

Reconnaissance Survey of Selenium in Water and  
Avian Eggs at Selected Sites Within the Phosphate  
Mining Region Near Soda Springs, Idaho  
May-June, 1999

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## ABSTRACT

The Phosphoria Formation in the northwest United States, a marine sedimentary deposit of Permian age, extends over thousands of square kilometers including portions of Montana, Idaho, Wyoming, and Utah. High concentrations of selenium are leached from waste shale dumps (overburden dumps) associated with phosphate mining in southeast Idaho and have recently resulted in documented cases of downgradient selenium poisoning among horses and sheep. The objective of this reconnaissance survey was to determine if nesting waterbirds were being exposed to hazardous levels of selenium at a selected set of highly contaminated downgradient ponds and wetlands. During the spring of 1999, potentially high-risk sites (based on water concentrations of selenium measured during the fall of 1997) were visited and assessed with regard to presence or absence of suitable habitat for breeding waterbirds. Water samples were collected at all sites (N=30) and avian eggs were randomly sampled at sites with breeding activity (N=15). Avian eggs were artificially incubated to produce embryos that were sufficiently developed to assess for external overt abnormalities. The water and avian egg samples were analyzed for selenium content. About one-third of the water samples exceeded 50 ug/L total recoverable selenium. Avian eggs across a wide spectrum of species, ranging from yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) to sandhill cranes (*Grus canadensis*), exhibited distinctly elevated selenium concentrations, ranging as high as 80 ug/g (dry weight) in American coot eggs (*Fulica americana*). Of 74 avian eggs sampled, 57 eggs (77%) contained at least 10 ug/g selenium which is an adverse effects threshold identified in experimental studies with mallards. Embryonic abnormalities were detected. This survey confirmed that worst-case conditions in southeastern Idaho yielded selenium concentrations in avian eggs that were comparable to other sites in the western United States where widespread selenium poisoning of waterbirds

has been fully documented, although the high risk sites identified in this survey did not appear to be exposing regionally significant numbers of breeding waterbirds. Based on the findings of this very limited spatio-temporal survey which, nonetheless, yielded scores of highly selenium-exposed avian eggs, it is recommended that a much more extensive spatio-temporal risk-targeted survey of avian exposure to selenium be conducted in the phosphate mining region of southeastern Idaho.

## INTRODUCTION AND OBJECTIVES

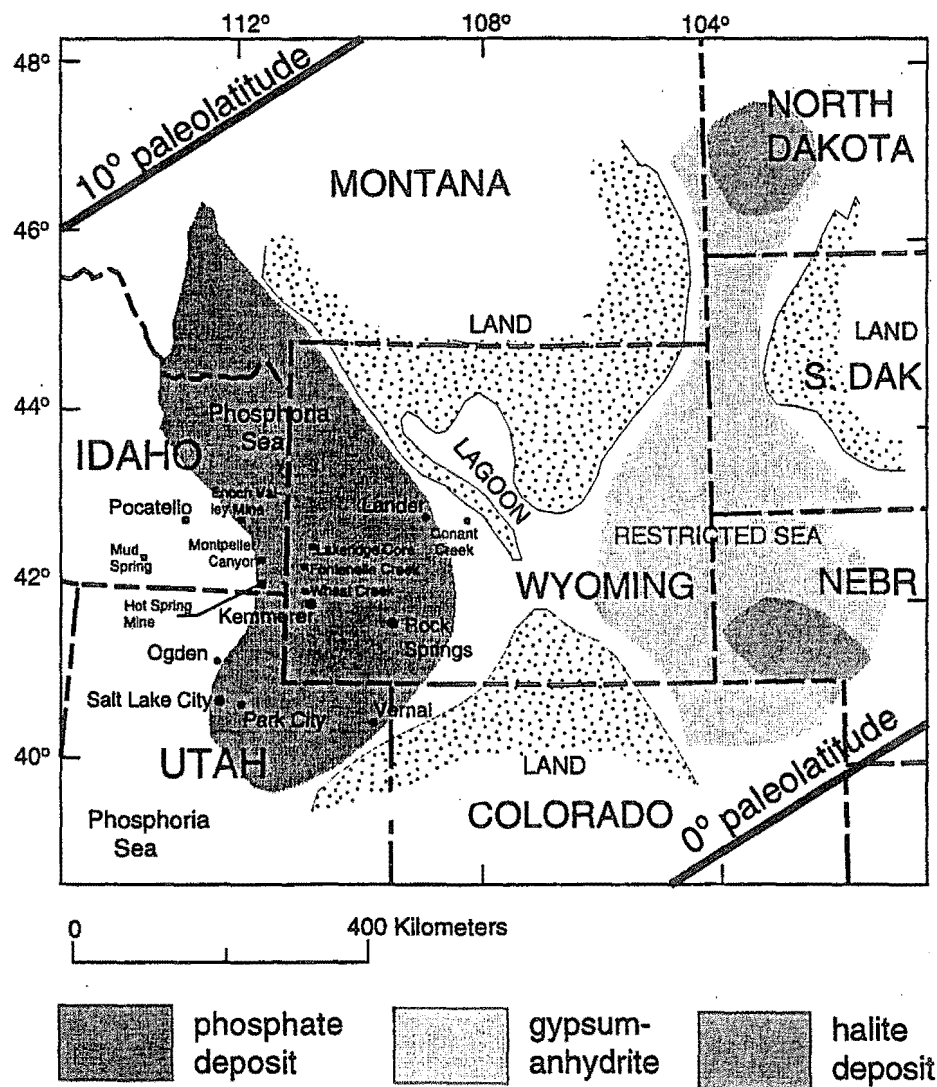
The Phosphate mining industry in the region near Soda Springs, southeastern Idaho, is based on exploiting a Phosphoria Formation of Permian age that extends over thousands of square kilometers across portions of four states, Idaho, Montana, Utah, and Wyoming (Figure 1; from Piper et al. 2000:57). High concentrations of selenium are leached from waste shale dumps (overburden dumps) associated with the mining of phosphate ore in southeastern Idaho (Presser et al., In Prep.). Elevated selenium concentrations in surface aquatic ecosystems elsewhere are now well documented to have presented substantive ecotoxicological risk to fish and wildlife in multiple case studies (*e.g.*, Skorupa 1998; Seiler et al. 1999; Hamilton 2002; Lemly 2002).

In 1996 and 1997 livestock that were grazing downgradient of at least two phosphate mines in southeastern Idaho were diagnosed as victims of chronic selenium poisoning (Montgomery Watson 1999). These toxic episodes among livestock created concerns within the U.S. Fish and Wildlife Service (Service) that federal trust resources, particularly anadromous fish and migratory birds might also be at risk of suffering adverse effects from excessive exposure to selenium (*e.g.*, Lemly 1999).

Prior to the spring of 1999, no sampling of avian eggs for selenium analysis had been conducted within the phosphate mining region of southeastern Idaho. Such sampling was deemed a priority information need, but the Service in Idaho had only limited funds that could be diverted to this need on short notice. Similar sampling efforts had been conducted by the Service in California for more than a decade (*e.g.*, Ohlendorf et al. 1986; Ohlendorf and Skorupa 1989; Moore et al. 1990; Skorupa and Ohlendorf 1991; Ohlendorf et al. 1993;



Figure 1. Geographic extent of the Phosphoria Formation in Montana, Idaho, Wyoming and Utah. Adapted from Piper et al. (2000:57).



Skorupa 1998). At the Service's national contaminants meeting during April, 1999, staff from Idaho approached staff from California for possible assistance with this matter. At the time, staff in California were collaborating with a PhD student at the University of California, Davis, on a dissertation project titled, "Toxicokinetics of selenium in the avian egg: comparisons between species differing in embryonic tolerance" (Detwiler 2002). This student had a need for highly contaminated avian eggs from nature. Upon reviewing preliminary data regarding concentrations of selenium in surface impoundments in southeastern Idaho (Montgomery Watson 1998) it was concluded that there was a reasonable chance that highly contaminated eggs could be obtained and therefore the student offered to assist with field collections and to provide selenium analyses of water and egg samples free of charge. This offer made it feasible for Service staff from California and Idaho to conduct a one-season, targeted, reconnaissance survey on the small budget available from the Service in Idaho.

Accordingly, there were two primary objectives of this reconnaissance survey. The first objective was to maximize the likelihood of obtaining highly contaminated avian eggs for use in the PhD dissertation project. The second objective was to assess what levels of avian selenium exposure were associated with a selected set of surface water impoundments that were at the upper end of measured waterborne selenium concentrations in a broad survey of the southeastern Idaho phosphate mining region (Montgomery Watson 1998).

Selenium-contaminated impoundments appear to present greater risks to wildlife than selenium-contaminated streams or rivers (*e.g.*, Skorupa 1998; Seiler et al. 1999) and therefore survey efforts were targeted toward surface impoundments and wetlands. Montgomery Watson (1998:Table 3-2) reported waterborne selenium concentrations for 26 surface water impoundments sampled during the fall of 1997. Those results ranged from a high of 185 ug/L

(ppb) selenium down to 0.4 ug/L. Impoundments with greater than 2 ug/L selenium are widely considered as potentially dangerous to breeding waterbirds (*e.g.*, DuBow 1989; Skorupa and Ohlendorf 1991; Peterson and Nebeker 1992; CAST 1994; Maier and Knight 1994; Van Derveer and Canton 1997; Skorupa 1998). The sampling strategy for this reconnaissance survey was to start at the top (most contaminated end) of the Montgomery Watson list and work our way as far down the list as our budget would allow.

## METHODS

Sampling Sites– Initial priorities for sampling sites were determined based on the selenium results reported by Montgomery Watson (1998) for a regional survey conducted in the fall of 1997. Ponds and reservoirs listed in Table 3–2 of the Montgomery Watson report were targeted for sampling in order from highest to lowest waterborne selenium concentrations. Streams and rivers were not targeted for sampling because they were viewed as less likely to represent worst–case selenium exposure conditions for breeding waterbirds and one of the primary objectives of the survey was to provide the “hottest” eggs possible for use in a University of California, Davis, PhD dissertation project. It became apparent very early in the survey efforts that many ephemeral vernal wetlands that are attractive to breeding birds were present during the spring season, but would not have been available for sampling by Montgomery Watson (1998) during the fall, 1997, survey of waterborne selenium. Therefore, such sites that appeared to be very suitable for breeding birds or that appeared to be directly downstream of a significant potential source of selenium (*e.g.*, directly downstream of a phosphate mine waste rock dump) were opportunistically sampled to the extent that time and budgetary constraints allowed.

Although water samples and avian egg samples were randomly collected from each sampling site, the sampling sites themselves were not randomly selected from among all such sites in the larger landscape. Sampling sites were nonrandomly targeted based on information available to the authors that identified each site as having the potential to be a high–risk site for exposure of breeding waterbirds to selenium. Of highest initial concern to the Service was identifying the order–of–magnitude for worst–case risk scenarios associated with mobilization of selenium into aquatic habitats by the phosphate mining activities in southeastern Idaho. If worst–case scenarios presented

minimal risk, there would be no need for further investigation.

Survey Timing – An attempt was made to time the survey to coincide with the initial peak in local avian breeding activity. The first round of field collections was conducted between May 11–14, 1999. This period included a snowfall event (Photo 1) and proved to be a little early for avian breeding activity except



Photo 1

Snowfall during May, 1999  
survey period.

for large-bodied species such as Canada goose (*Branta canadensis*; Photo 2) and sandhill crane (Photo 3). At the end of this survey period Service California



Photo 2 – Canada goose and  
sandhill crane nesting site during  
May survey period (snow present).



Photo 3 – Sandhill crane nest  
sampled May 12, 1999.

staff and the UC–Davis graduate student returned to California to reserve the remaining budget for a later second round of field collections. One replicate, and three supplemental water samples were collected by Service Idaho staff on May 21, 1999.

The second round of field collections was conducted during June 20–24, 1999. During this survey period a much broader diversity of avian species were exhibiting peak breeding activity including relatively small-bodied passerines such as American robin (*Turdus migratorius*; Photo 4). Whereas the first round of field collections yielded more water samples than avian egg samples, the second round of sampling was more focused on avian eggs. Many of the vernal wetlands sampled for water during the May survey were already drying-up by the time of the June survey. Few new sites were visited during the June survey. This second round of field collections was primarily focused on the sites that had been “scouted” in May and sampled for water. Additional avian eggs were



Photo 4 – An American robin nest at Smoky Canyon Mine tailings pond number 1.

supplementally collected by Service Idaho staff on May 28<sup>th</sup>, June 1<sup>st</sup>, and June 30<sup>th</sup>, 1999. These supplemental samples were collected as part of planned return visits to sites previously checked during the primary May and June survey periods.



Water Sampling – All water samples were collected as grab samples by wading a few feet into ponds, reservoirs, and wetlands and collecting water from just below the surface. Samples were generally collected from portions of respective water bodies that were less than 30 cm total depth. Care was taken not to include any disturbed sediments (from wading) in the sample. During the May survey, when most water samples were collected, samples were collected in 20 ml polyethylene scintillation vials. The few water samples collected during the June survey were collected in 20 ml borosilicate glass vials with polyseal caps. All vials were rinsed at least twice with native water just prior to obtaining the water sample that was to be retained in the vial. No air space was left in filled vials. After collection, each vial was labeled with a location number that was also recorded in the fieldnotes log. Water samples were not filtered nor were they acidified. Unfiltered samples facilitate analysis for total recoverable selenium as opposed to dissolved selenium only. In lentic aquatic habitats measures of dissolved selenium can substantively underestimate the concentration of total recoverable selenium in the water column (*e.g.*, Fujii 1987). The samples were not acidified because there were no plans for speciation or isotope analyses and it was not anticipated that long-term storage of the samples would be necessary. For example, the water samples collected during May 11–14, 1999, had all been analyzed in duplicate by May 17, 1999. Samples were transported and stored at ambient field and room temperatures prior to analysis. No field measurements of water parameters were conducted. The samples were collected solely for selenium analysis at U.C. Davis.

Nest Searching and Egg Sampling – At potential sampling sites suitable habitat was searched for adult birds exhibiting courtship, nest building, food delivery, or nest defense (*i.e.*, territorial) behavior. Searching was done in as non-disruptive a manner as possible. Nest searching was conducted only

during climatic conditions that are functionally thermo-neutral for developing avian eggs, particularly with regard to the potential risk of eggs getting overheated. Locations of individual nests were not physically marked because re-visits were not routinely anticipated.

Once located, general notes were recorded regarding nest location and condition, species identification, and clutch size. Usually one to two eggs were randomly sampled per clutch. Unless there were one or more eggs in the clutch that were in some way distinctive (*e.g.*, runt egg, unpigmented egg, *etc.*), the random sample egg(s) was simply the one(s) nearest to the direction of approach to the nest. When a distinctive egg(s) was present that could subconsciously or consciously influence which egg(s) was casually selected as the random sample, a formal randomization procedure was used to determine which egg(s) would be collected. There were a few cases in which nests were located after they had already been partially predated (Photos 5 & 6), or after they had already begun to be flooded out. In such cases, the entire remaining clutch was salvaged for selenium analysis.



Photo 5 – Partially predated mallard nest. Seven undeveloped eggs were salvaged and successfully incubated to late stage.



Photo 6 – Carcass of predated mallard salvaged from nest in Photo 5. A breast muscle sample was obtained from carcass.



Sampled eggs were marked on the long side with an identification code using a sharpie felt-tipped pen and placed in a foam padded box (Photo 7) for transport from the field to an incubator.



Photo 7 – Foam padded box with cutouts for securely transporting eggs from the field.

All eggs were collected under authority of state collecting permit no. 990505 issued to Robert Brassfield and authorizing final depository or disposition of the specimens at U.C. Davis and destruction of the specimens for the purpose of chemical analyses. The state of Idaho does not require Service employees to possess a federal collecting permit. As species of breeding birds were encountered that were not anticipated prior to the original permit application, supplemental authorizations were obtained to expand the species list covered by the state collecting permit.

Artificial Incubation of Eggs – In order to maximize the interpretive value of collected eggs an attempt was made to obtain an assessable embryo from every egg collected. Embryos must be developed to a minimum of about one–

third to one-half the normal full incubation term to be assessable for external overt abnormalities. To accomplish this, a standard 3-shelf tabletop commercial incubator with automatic shelf-turner was set up in residential garage space provided by the U.S. Forest Service in Soda Springs to serve as a holding incubator (Photo 8). Eggs were held in this incubator during the time between being collected and being transported to U.C. Davis (*i.e.*, <1–7 days).



Photo 8 – Garage space (used for storing snowmobiles) provided by U.S. Forest Service for setting up the holding incubator (redwood cabinet in upper center of photo). Also shown is the lower capacity portable incubator (plastic case with blue bottom in upper left of photo) used while eggs were being driven from Idaho to California.

Unprocessed eggs were transported to U.C. Davis via pick-up truck in a portable incubator (Photo 8) with a DC power source allowing it to be operated off the cigarette lighter outlet of the truck. Upon arrival at U.C. Davis, eggs were transferred from the portable incubator to a standard 3-shelf tabletop commercial incubator with automatic shelf-turner for the remainder of

incubation. The target incubation temperature was 99.5°F and the target humidity in the tabletop incubators was 55–65% relative humidity. There was no humidity control in the portable incubator. Egg turning frequency was one complete turning cycle every two hours. Incubator temperatures were checked no less than daily and fine adjustments were made as necessary. Each egg was logged into the incubator by initializing an egg data form that recorded the collection date, incubator set date and time, egg identification, species, collection location, initial incubation stage (estimated by water floatation; *e.g.*, Hays and LeCroy 1971), and miscellaneous notes (if any). Once eggs were set in the incubator, the incubation stage was re-estimated about every 2–3 days on average to confirm that they were progressing. Eggs which failed to progress in incubation stage were removed from the incubator and processed. The target incubation stage for processing eggs that were successfully set (*i.e.*, that progressed in incubation stage) varied from about 12–18 days of development depending on species and which part of the U.C. Davis dissertation project a particular egg was targeted for.

Egg Processing – All except 8 of the 74 eggs collected during this survey were processed at U.C. Davis. The remaining 8 were processed in the Service's Contaminants Division Laboratory at the Sacramento Fish and Wildlife Office.

At U.C. Davis, eggs that were successfully set in an incubator and that developed to the target incubation stage (12–18 days development) were processed to separate the egg contents into three tissue compartments--representing the embryo corpus, yolk sac, and extra-embryonic membranes and fluids (hereafter referred to as the "extracorporeal fraction"). Eggs were opened at the air-cell end using a clean stainless steel scissors to cut out a circular opening in the eggshell. Embryos were excised from the rest of the egg contents by clipping the umbilicus at 1 cm from its egress at the abdominal

cavity. The extracorporeal fraction -- consisting of the extra-embryonic membranes (chorioallantois, amnion, and shell membrane cap at the air sac) -- was separated in addition to any remnant albumen, amniotic fluid, and blood. These compartments were difficult to readily isolate from each other, and contain a mixture of intact albumen proteins and free amino acids (from the albumen and amniotic sacs), endogenous compounds (from blood), as well as wastes and depuration products (from the chorioallantois). The remnant yolk sac (membrane and yolk) was thereby isolated from the other tissue compartments. All sample fractions were immediately flash-frozen in liquid nitrogen to prevent proteolytic degradation.

Data collected during this process and recorded on the same egg data form initiated prior to placing an egg into an incubator included: process date, process time, sample number, egg length (mm), egg breadth (mm), total gross mass of egg (g), total gross mass of egg contents (g) (after removal from the eggshell), embryo mass (g), extracorporeal fraction mass (g), yolk sac mass (g), and the embryo age (estimated stage of development) and embryo status (alive or dead, overtly normal or abnormal). Any other additional relevant observations (such as descriptions of embryonic abnormalities (*cf.*, Hoffman and Heinz 1988), or embryo malpositioning; (*cf.*, Romanoff 1972) were recorded in the notes section of the egg data form. For mallard (*Anas platyrhynchos*) eggs, embryonic stage of development was estimated using the photographic index published by Caldwell and Snart (1974). Caldwell and Snart (1974) was also used as a rough guide for aging American coot embryos. Incubation stages of shorebird embryos were aged using an unpublished photographic index for American avocets (*Recurvirostra americana*) produced via a collaborative effort between Service Sacramento staff and the Avian Science Department, U.C. Davis (attached as Appendix A). All other species'

embryos were compared to a photographic index for embryonic development of the domestic chicken (*Gallus domesticus*) (Hamburger and Hamilton 1951) and calibrated based on the respective full-term incubation intervals for the species in question relative to the full-term incubation interval of 21 days for the domestic chicken.

Eggs processed at the Service's Sacramento Fish and Wildlife Office (and eggs that did not successfully incubate at U.C. Davis) were not partitioned into separate embryo corpus, extracorporeal fraction, and yolk sac tissue compartments. These eggs were opened at the air cell end and the entire contents emptied into 1 oz. or 2 oz. dinolon sample jars. Most of the eggs (5 of 8) processed in Sacramento were not sufficiently developed to provide assessable embryos. For those eggs developed sufficiently to yield an assessable embryo, the embryo was separated from the yolk sac and extracorporeal fraction and briefly placed in a polystyrene hexagonal weighing boat to allow examination of the embryo for overt external abnormalities. Upon completion of a brief visual inspection of the embryo it was returned to the same dinolon sample jar containing the remainder of that egg's contents. Samples were then immediately placed in a freezer and stored until transported to U.C. Davis for chemical analysis.

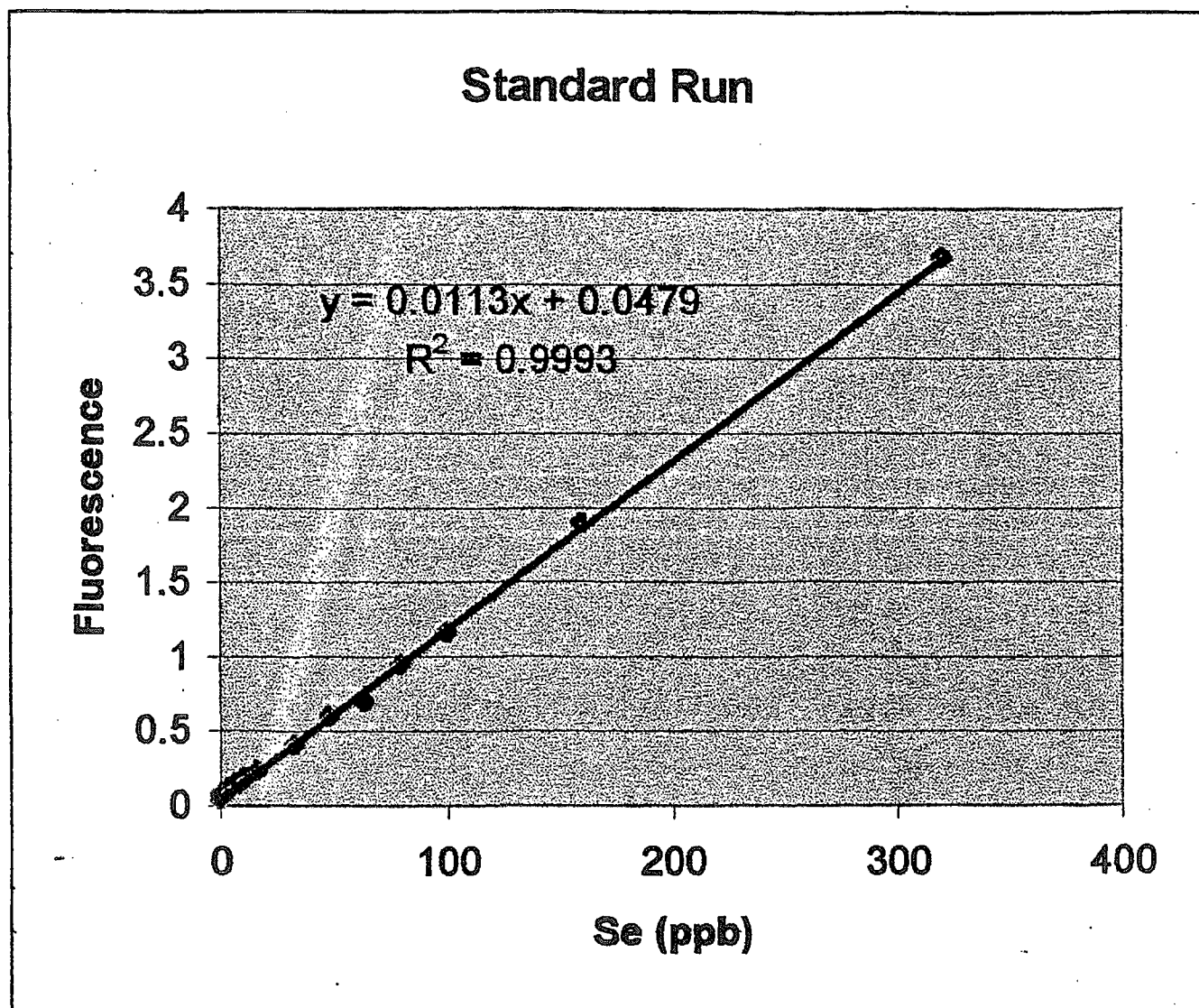
For eggs processed in Sacramento, data entered into an egg catalog included, species identification, collection site, nest number, egg letter, date egg was collected, egg length (cm), egg breadth (cm), total gross mass of egg (g), total gross mass of egg contents (g) (after removal from the eggshell), the embryo age (estimated stage of development) and embryo status (alive or dead, overtly normal or abnormal), sample type (random, nonrandom), and the presence or absence of embryo malpositioning (*cf.*, Romanoff 1972). In addition, any relevant miscellaneous notes were also recorded in the egg catalog.

Selenium Analyses – All selenium analyses were conducted in the laboratory of Dr. Theresa Fan, Department of Land, Air, and Water Resources, U.C. Davis. Both the water samples and the avian eggs (after being homogenized and freeze-dried) were analyzed for total selenium utilizing a microdigestion and fluorescence-based microanalysis briefly described in Fan and Higashi (1998:549). The fluorescence method was modified from the Analytical Methods Committee (1979). Briefly, the method employed nitric acid microdigestion to convert organic selenium into selenium oxyanions, which were then reduced to selenite by 6 N HCl at 105°C, followed by derivatization with 2,3-diaminonaphthalene to form the corresponding piazselenol derivatives, which were then quantified by fluorescence in a Perkin-Elmer LS-3 spectrophotometer at an excitation wavelength of 374 nm and emission wavelength of 522 nm. The detection limit for the fluorescence method was in the submicrogram-per-liter range, based on 500 uL of water or <5 mg of egg tissue homogenate. The typical correlation coefficient obtained for a standard curve of 20 selenium standards (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.6, 3.2, 4.8, 6.4, 8, 10, 16, 32, 48, 64, 80, 100, 160, and 320 ug/L SeO<sub>4</sub> in 0.1N HNO<sub>3</sub>) was better than 0.99 (Figure 2). In addition, samples with a selenium spike were analyzed to determine the bias of the analysis, which was consistently within 10 percent of predicted values. Duplicate analyses were run for each water sample, and triplicate analyses for each avian egg sample (Detwiler 2002). Standard practices for the digestion, reduction, derivatization, and fluorescence reading procedures employed for sample analyses may be obtained on request from Dr. Theresa Fan or through Dr. Joseph Skorupa (Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service).

Dr. Fan's lab is not a U.S. Fish and Wildlife Service contract laboratory. Therefore the analytical quality assurance measures practiced in Dr. Fan's lab necessarily differ from the requirements imposed upon Service contract



Figure 2. Standards run for selenium analysis of Idaho water samples by piazselenol/fluorescence May 17, 1999.

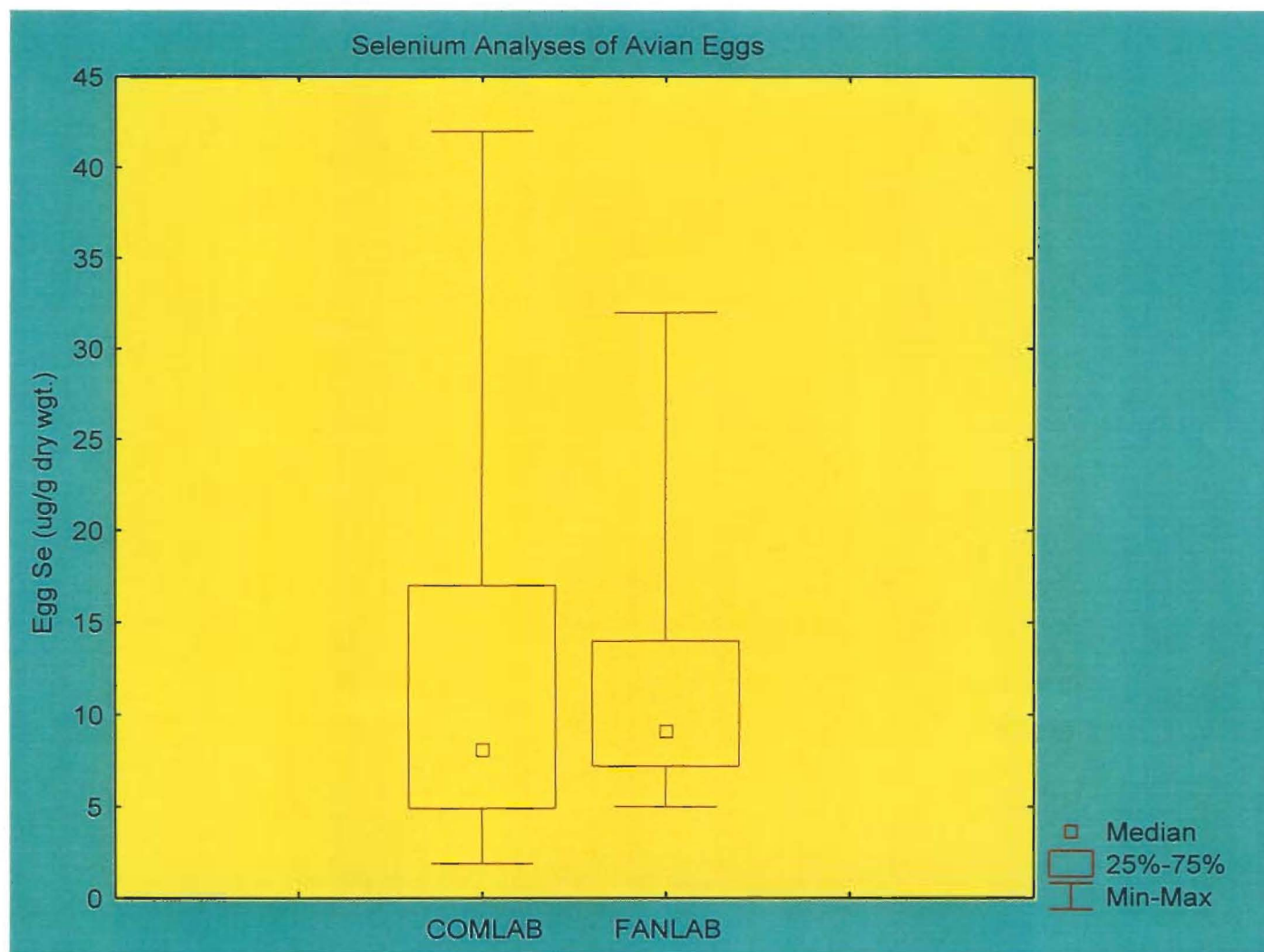


laboratories by the Service's Patuxent Analytical Control Facility (PACF 1997). However, the same PhD student conducting the selenium analyses for this survey, was also collaborating on another study in which two sibling eggs were removed from each nest in populations of breeding killdeer and black-necked stilts (*Himantopus mexicanus*) at Kesterson Reservoir (CH2M HILL 1999). One sibling egg from each nest came to U.C. Davis for artificial incubation and the other sibling egg from each nest was sent directly to a commercial lab that strictly conforms with the Service's PACF quality assurance requirements for contract laboratories. The eggs sent to U.C. Davis were ultimately processed and analyzed for selenium in Dr. Fan's lab following the identical practices employed to generate the egg selenium results for this (Idaho) survey. Thus, for each Kesterson Reservoir egg analyzed in Dr. Fan's lab, there was a sibling egg analyzed for selenium by the equivalent of a Service contract laboratory. Neither Dr. Fan's lab nor the commercial lab had access to the other lab's results prior to conducting their analyses (*i.e.*, the comparisons are for "double-blind" results).

Sibling eggs are not the same as true sample splits because the selenium content of avian eggs within the same clutch does vary, with such variance increasing as the degree of environmental contamination increases (Skorupa et al., unpubl. data). However, sibling eggs do show a high degree of correlation in selenium content, and therefore can serve as at least a rough check on the consistency of results from Dr. Fan's lab relative to a commercial laboratory. Results for 42 pairs of sibling eggs are available for comparison. The mean dry-weight selenium content reported for eggs sent to the commercial lab was 10.8 ug/g and the mean reported for eggs analyzed in Dr. Fan's lab was 11.5 ug/g, a relative percent difference of only 6.5%. The respective dry-weight medians were 8.2 and 9.2 ug/g. A box and whisker plot (Figure 3) of the comparative results shows that the two labs produced results with highly



Figure 3. Comparison of Analytical Chemistry Results for Paired Sibling Killdeer and Black-necked Stilt Eggs (N=42 sibling pairs).



consistent central tendency, but that the commercial lab results included wider extreme values on both ends (low and high).

### GIS Mapping and Statistical Analyses – Global Positioning System (GPS)

coordinates for water and avian egg sampling locations were obtained using a Magellan GPS Blazer 12 satellite navigator (Magellan Systems Corporation, San Dimas, CA). The GPS Blazer 12 is a self-contained hand-held GPS receiver designed for general purpose position locating and navigation. GPS coordinates were recorded in decimal-minute format based on NAD27 map datum.

The original decimal-minute format GPS coordinates were converted to decimal-degree format and digital files were transmitted to the U.S. Geological Survey (USGS; via Dr.'s Philip Moyle and J. Douglas Causey) for inclusion in USGS Arcview coverages being developed for the U.S. Western Phosphate project. For this report, a Geographic Information System (GIS) plot of the sampling locations was prepared on a 1:100,000 series DLG base map from USGS (prepared by Don Hovik, Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service). The map projection was UTM Zone 12, NAD 27. That GIS plot is further broken down into seven sampling zones matched to specific phosphate mines mapped by USGS ("Types of Phosphate Mining Disturbance and Bird Egg and Water Sample Site, Soda Springs 1:100,000 Quad, Idaho"; Version 0.1a; Draft Map, April 25, 2000).

All compilation and statistical manipulation of analytical chemistry results (data) for selenium were conducted using one or more of three statistical software packages, Statistica 5.0 or 6.0 (StatSoft, Inc., Tulsa, OK), StatXact 4 (CYTEL Software Corp., Cambridge, MA), and LogXact 4 (CYTEL Software Corp., Cambridge, MA).

## RESULTS

Site Visits Narrative – *May 11, 1999*: Conducted initial survey of Dry Valley with Jeff Jones, U.S. Forest Service, following a meeting with Rick Bullis (Dry Valley/North Maybe Mines).

Water sample number 1 was collected from a (vernal?) hillside seep feeding into a beaver pond approximately 0.8 km east of the intersection of R. Allen Ranch and Slug Creek Roads. No avian eggs were collected. Waterborne selenium was 2.5 ug/L.



Photo 9 – Beaver pond along railroad bed that was receiving seep water (water sample no. 1)

Water sample number 2 was collected from a small (vernal?) roadside pond near Chicken Creek, northwest Dry Valley. No avian eggs were collected. Waterborne selenium was 56 ug/L.





Photo 10 – Small (vernal?) pond in northwest Dry Valley from which water sample no. 2 was collected.

Water sample number 3 was collected from a horse pasture in Dry Valley that was one of the sites of diagnosed livestock poisoning (selenosis). No avian eggs were collected. Waterborne selenium was 803 ug/L.

Photo 11 – Dry Valley horse pasture. Water sample no. 3 was collected from creek running through the pasture (the dark band of vegetation in the mid-background of photo). Maybe Creek is believed to be the source of the water that was sampled.



Water sample number 4 was collected from a spring adjacent to Maybe Creek within Maybe Canyon. No avian eggs were collected. Waterborne selenium was 716 ug/L.



Photo 12 – Maybe Canyon downstream from a cross-valley fill (snow-covered white wall in upper right quadrant of photo). Water sample no. 4 was collected between this point and the cross-valley fill.

Water sample number 5 was collected from a seep at the toe of the Maybe Canyon cross-valley fill. No avian eggs were collected. Waterborne selenium was 1,394 ug/L.

Photo 13 – The toe of the Maybe Canyon cross-valley fill. Water sample no. 5 was collected near here.





Water sample number 6 was collected from the lower of two settling ponds on Maybe Creek near the bottom of Maybe Canyon. Waterborne selenium was 897 ug/L. One American robin egg (Egg sample number 1) was sampled from a nest in the shoreline riparian zone at this site. The egg was fresh (unincubated) at collection and was successfully set in the holding incubator. The egg yielded a live-normal assessable embryo and the whole-egg selenium content was 8.7 ug/g, dry weight basis.



Photo 14 – Nest of American robin at the lower settling pond on Maybe Creek. Site of water sample no. 6.

Water sample number 7 was collected from a (vernal?) “pothole” puddle in a wet pasture containing numerous such puddles near the Champ Mine pit, Upper Dry Valley. No avian eggs were collected. Waterborne selenium was 4.1 ug/L.

Photo 15 – Vernal “pothole” puddles in Upper Dry Valley. Water sample no. 7 was collected from such a puddle.



Water sample number 8 was collected from a seep on a bench just above the Champ Mine pit, Upper Dry Valley. No avian eggs were collected, although a Canada goose was presenting a distraction display down in the pit (lake). Waterborne selenium was 6.0 ug/L.



Photo 16 – Seep near Champ Mine pit where water sample no. 8 was collected.



Photo 17 – Champ Mine pit lake.

*May 12, 1999:* Conducted initial survey along Upper Angus Creek following meeting with Rob Squires (Wooley Valley Mine).

Water sample number 9 was collected at Upper Angus Creek Reservoir (Montgomery Watson 1997 water sampling station number 43). No avian eggs were collected, although several mallards were present. No photos were taken. Waterborne selenium was 22 ug/L. Montgomery Watson (1998:Table 3-2) reported waterborne selenium of 1.5 ug/L during fall, 1997.

Water sample number 10 was collected from a (vernal?) sediment retention basin at the east base of the haul road (along Upper Angus Creek) in the south-central portion of Little Long Valley. No avian eggs were collected, although Brewer's blackbirds (*Euphagus cyanocephalus*) were present. No photos were



taken. Waterborne selenium was 4.2 ug/L.

Water sample number 11 was also collected from a (vernal?) sediment retention basin at the east base of the haul road (along Upper Angus Creek) in the north-central portion of Little Long Valley. No avian eggs were collected. Relatively abundant aquatic macroinvertebrates were present in water and the presence of frogs (unidentified species) was also noted. Waterborne selenium was 4.4 ug/L.



Photo 18 – Haul road sediment basin in north-central portion of Little Long Valley. The haul road is at the top of the embankment in upper part of the photo. Water sample no. 11 was collected here.

Water sample number 12 was collected from a vernal drainage pond along the west side of the haul road along Upper Angus Creek in north Little Long Valley. This pond contained a few dead snags (trees) and a belted kingfisher (*Megasceryle alcyon*) was perched in one of the snags. Waterborne selenium was 7.3 ug/L. An American robin egg was sampled at this site on June 24<sup>th</sup> (Egg sample number 74). The egg was fresh and unincubated (from an incomplete clutch) at the time of collection and was successfully set in the holding



incubator. However, the incubator thermostat malfunctioned just prior to departing for California and this egg was among the final group of six eggs in the holding incubator at that time, all of which became lethally overheated before the malfunctioning thermostat was discovered. The embryo had incubated for about 5 days, long enough to have advanced to an assessable stage, and was overtly normal. The selenium content of the whole egg was 5.9 ug/g dry-weight basis.

Water sample number 13 was collected from a vernal puddle just upslope of Montgomery Watson station no. 41 (Unit III Panel F Pond; 98 ug/L waterborne selenium in fall, 1997). This puddle was sampled because killdeer (*Charadrius vociferus*) were displaying nearby, but a nest was never located. No avian eggs were collected. No photos were taken of the puddle. Waterborne selenium in the puddle was 4.1 ug/L.



Photo 19 – Montgomery Watson 1997 water sampling station no. 41. Not sampled during this survey due to lack of avian activity.

Water sample number 14 was collected from a pool of water that appeared to be drainage from a reclaimed (*i.e.*, revegetated) waste rock pile along the northwest end of Little Long Valley. This pool of water was sampled because a pair of sandhill cranes were nesting at the edge of the pool (the nest depicted in Photo 3, note the water in the upper portion of photo 3). The waterborne selenium was 772 ug/L. A crane egg was sampled (Egg sample number 2). This egg was not successfully set in the holding incubator. It did not yield an assessable embryo and had a whole-egg selenium content of 5.3 ug/g dry-weight basis. In order to investigate within-clutch variability of egg selenium in such a large-bodied and wide-ranging species of bird, and to obtain an assessable embryo, the sibling egg from this crane nest was sampled June 1<sup>st</sup> (Egg sample number 21). This sibling egg contained an advanced stage, live-normal embryo, and had a whole-egg selenium content of 7.3 ug/g dry-weight basis.

Photo 20 – Sandhill crane displaying on slope of reclaimed waste rock pile upgradient of drainage pool with crane nest on shoreline (see photo 3). Egg sample nos. 2 and 21 from this nest in NW Little Long Valley.



Water sample number 15 was collected from a vernal drainage sink (which was dry when revisited in June) near the entrance of the access road to Wooley Valley Mine. No avian eggs were collected. No photos were taken. Waterborne selenium was 230 ug/L.

The next set of sites visited May 12<sup>th</sup> were associated with the Enoch Valley Mine and Mike Vice (Enoch Valley Mine) guided the survey of these sites.

Montgomery Watson station number 36 (Enoch Valley Mine Haul Road Pond; 65 ug/L waterborne selenium in fall, 1997) was visited, but no water sample was collected due to lack of avian activity and general lack of promising nesting habitat.



Photo 21 – Enoch Valley Mine Haul Road Pond, Montgomery Watson 1997 water sampling station no. 36.

Montgomery Watson station number 35 (Enoch Valley Mine Tipple Pond; waterborne selenium of 71 ug/L in fall, 1997) was visited. Little avian activity was noted. Killdeer were present and potential nesting “gravel” for killdeer was also present. No water sample was collected during this visit, but the site was



noted for a potential follow-up visit if higher priority sites with greater potential for avian egg sampling were not located.



Photo 22 – Enoch Valley Mine Tipple Pond,  
Montgomery Watson 1997 water sampling station  
no. 35. Potential killdeer nesting habitat in foreground.

Montgomery Watson station number 31 (Enoch Valley Mine Stock Pond; 25 ug/L waterborne selenium in fall, 1997) was visited. No avian activity was noted. The digital photo file for this site became corrupted and was unretrievable. No water sample was collected due to lack of avian activity and lack of promising nesting habitat.

Water sample number 16 was collected from Montgomery Watson station number 33 (Enoch Valley Mine West Pond; 21 ug/L waterborne selenium in fall, 1997). Waterborne selenium was 68 ug/L. A Sandhill Crane nest was present in this pond and one egg was sampled (Egg sample number 3). This egg was not successfully set in the holding incubator. No assessable embryo was obtained. The whole-egg selenium content was 4.2 ug/g dry-weight basis.



Photo 23 – Enoch Valley Mine West Pond, Montgomery Watson 1997 water sampling station no. 33. Dark spot in center of photo is a sandhill crane nest. Water sample no. 16 and egg sample no. 3 were collected at this site.

Montgomery Watson station number 32 (Enoch Valley Mine Bat Cave Pond; 16 ug/L waterborne selenium in fall, 1997) was visited. A spotted sandpiper (*Actitis macularia*) was present on the shore, but otherwise little avian activity was noted. No water sample was collected.

Photo 24 – Drainage gulley draining into Enoch Valley Mine Bat Cave Pond (foreground), Montgomery Watson station no. 32. Waste shale is being used to form erosion checks in this gulley (e.g., at lower end of snow patch), perhaps contributing to selenium inflow (Mike Vice, personal observation).



Montgomery Watson station number 34 (Enoch Valley Mine South Pond; 9 ug/L waterborne selenium in fall, 1997) was visited very briefly. This site exhibited some of the heaviest avian activity of the entire survey, especially for waterbirds such as pied-billed grebe (*Podilymbus podiceps*), American coot, and dabbling ducks (*Anas* spp.). However, it was too early in the season for the full seasonal renewal of emergent marsh vegetation. Thus, sampling was deferred until a later visit. This site was revisited June 23<sup>rd</sup>, when water sample number 38 was collected. Waterborne selenium was 68 ug/L. In addition, two American coot eggs were sampled (Egg sample numbers 63 and 64), two red-winged blackbird (*Agelaius phoeniceus*) eggs were sampled (Egg sample numbers 65 and 66) and a brown-headed cowbird (*Molothrus ater*) egg was sampled (Egg sample number 67). The coot eggs were sibling eggs. Neither egg was successfully set in the holding incubator, thus neither egg yielded an assessable embryo. The whole-egg selenium contents of these eggs were 80 and 73 ug/g dry-weight basis. One of the red-winged blackbird eggs, with a whole-egg selenium content of 13 ug/g dry-weight basis, was a fail-to-hatch egg remaining in a nest that also contained 4 live-normal nestlings. The other red-winged blackbird egg was a fresh, unincubated egg. No assessable embryo was obtained from this egg, and the whole-egg selenium content was 23 ug/g dry-weight basis. The brown-headed cowbird egg was the only egg present in the nest it was sampled from (dump egg?). It was undeveloped and no assessable embryo was obtained from it. The whole-egg selenium content was 4.9 ug/g dry-weight basis. The coot eggs and the blackbird eggs were part of the final group of six eggs that overheated when the holding incubator thermostat malfunctioned and were collected only the day before the malfunction, therefore precluding any assessable embryo development prior to the eggs failing.



Photo 25 – Enoch Valley Mine South Pond, Montgomery Watson 1997 water sampling station no. 34. Photo taken in May, 1999, before full development of lush beds of emergent vegetation attractive to nesting waterbirds.

Montgomery Watson station number 37 (Enoch Valley Mine North Pond; 185 ug/L waterborne selenium in fall, 1997) was visited. No avian activity was noted during the visit and habitat conditions for breeding birds did not look promising. Thus, no water sample was collected. This pond was receiving water from drainage runways constructed from waste shale. This might explain why this sampling station yielded the highest waterborne selenium result of any impoundment surveyed by Montgomery Watson during the fall of 1997.

Photo 26 – Enoch Valley Mine North Pond, Montgomery Watson 1997 water sampling station no. 37. Note the dark tongue of the waste shale drainage runway that feeds into this pond from the left side of the photo.





Photo 26 – Close-up of waste shale drainage runway which conveys runoff into Enoch Valley Mine North Pond. This shale possibly serves as a ready source of selenium leachate. Such effects were not considered when the drainage runway was constructed (Mike Vice, personal communication).



Montgomery Watson station number 30 (Enoch Valley Mine Shop Pond; 5.1 ug/L waterborne selenium in fall, 1997) was visited. The site appeared promising for avian nesting activity, including an ongoing sandhill crane nest, however, the site held special significance to the shop workers (who considered the nesting cranes in particular as almost pets; Mike Vice, personal communication) and therefore disturbance of this site was avoided. No water or egg samples were collected.

Photo 27 – Enoch Valley Mine Shop Pond, Montgomery Watson 1997 water sampling station no. 30. Note promising marsh habitat for breeding birds and incubating sandhill crane near center of photo. Photo taken before seasonal renewal of marsh vegetation.





Montgomery Watson station number 26 (Henry Mine Smith Pond; 40 ug/L waterborne selenium in fall, 1997) was visited. This site was not readily accessible due to barbed-wire fencing and therefore was merely photographed to illustrate the presence of shoreline woody vegetation that could potentially support breeding birds.



Photo 28 – Henry Mine Smith Pond, Montgomery Watson 1997 water sampling station no. 26. Not sampled for this survey.

Montgomery Watson station number 27 (Henry Mine Center Henry Pond; 25 ug/L waterborne selenium in fall, 1997) was visited. Again, this site appeared to support relatively promising habitat for supporting at least small numbers of breeding birds, but access to the site was fenced off. Therefore the site was merely photographed to illustrate habitat conditions. It appeared that swallow (*Hirundo* spp.) nesting boxes had been erected at this site (?)

Photo 29 – Henry Mine Center Henry pond, Montgomery Watson 1997 water sampling station no. 27. Not sampled for this survey.



Water sample number 17 was collected from a beaver pond on the Little Blackfoot River north of Wooley Ridge (see Photo 2). Waterborne selenium was 3.6 ug/L. A Canada goose egg was sampled (Egg sample number 4) at this site and a neighboring sandhill crane nest was not sampled. The goose egg was successfully set in the holding incubator and ultimately yielded an advanced stage live-normal embryo. The whole-egg selenium content of the egg was 3.1 ug/g dry-weight basis. Killdeer and several species of dabbling ducks were also present at this site.

Water sample number 18 was collected from a beaver pond in south Enoch Valley. Killdeer and cinnamon teal (*Anas cyanoptera*) were present. No avian eggs were collected. Waterborne selenium was 4.5 ug/L.

Photo 30 – Cinnamon teal pair on shore of south Enoch Valley beaver pond from which water sample number 18 was collected.



Water sample number 19 was collected from Montgomery Watson station number 25 (Henry Mine Henry Pond; 6.7 ug/L waterborne selenium in fall, 1997). Waterborne selenium was 9.7 ug/L. Eared grebes (*Podiceps nigricollis*),



green-winged teal (*Anas crecca*), gadwall (*Anas strepera*), common goldeneye (*Bucephala clangula*) and killdeer were present. The site appeared to be fairly attractive to waterbirds. One killdeer egg was sampled (Egg sample number 5). The killdeer egg was successfully set in the holding incubator and eventually yielded an advanced stage live-normal embryo. The whole-egg selenium content was 16 ug/g dry-weight basis.



Photo 31 – Henry Mine Henry Pond, Montgomery Watson 1997 water sampling station no. 25. Water sample no. 19 and egg sample no. 5 were collected here. A killdeer nest was located on gravel substrate similar to that in the foreground of this photo.

Montgomery Watson station number 22 (Ballard Mine Dredge Pond; 150 ug/L waterborne selenium in fall, 1997) was visited. A pair of mallards flushed from this pond at our arrival. No water sample was collected. It was not expected that this would be a priority site for a revisit later in the nesting season, mostly due to the relatively small size of the pond.

Photo 32 – Ballard Mine Dredge pond, Montgomery Watson 1997 water sampling station no. 22. Note this site might better be described as a puddle than as a pond.



Water sample number 20 was collected from an extensive wetland complex (Woodall Spring) west of Solutia Corporation's asphalt-paved haul road west of the Conda Mine. This site supported a dense population of American coots and appeared to be promising nesting habitat. No avian eggs were collected during this visit because the contamination status of the site was unknown. It was decided that the site would be revisited for egg sampling if waterborne selenium proved to be highly elevated. Waterborne selenium was 2.5 ug/L. A replicate water sample (water sample number 35) was collected from this site by Service Idaho staff on May 21<sup>st</sup>. The replicate measure of waterborne selenium was 2.3 ug/L. No avian eggs were collected. No site photos were recorded.

*May 13, 1999:* Conducted an initial survey of sites associated with Conda Mine, guided by Ken Schiess (Exploration Engineer for the J.R. Simplot Company).

Water sample numbers 22 and 23 were collected from separate vernal puddles within the trace of the old (inactive) Conda Mine tailings pond. Waterborne selenium was 207 ug/L and 112 ug/L respectively for samples 22 and 23. A Canada goose nest was found about 30 m upslope of the puddle from which water sample number 22 was obtained. One egg was sampled (Egg sample number 6) and was successfully set in the holding incubator. This egg ultimately yielded a live-abnormal embryo. The embryo exhibited a slightly reduced lower bill. The whole-egg selenium content was 6.2 ug/g dry-weight basis.

Photo 33 – Canada goose nest at Conda Mine old tailings pond. Egg sample no. 6 was collected from this nest.





Photo 34 – Vernal puddles within the trace of the Conda Mine old (inactive) tailings pond. Water sample numbers 22 (near puddle) and 23 (far puddle) were collected here.

Water sample number 24 was collected from an extensive vernal marshy area on the south end of the Conda Mine old tailings pond. Waterborne selenium was 199 ug/L. This site presented some of the most impressive habitat for breeding waterbirds encountered during the entire survey. There was extensive shallow water brimming with macroinvertebrates (mostly mosquito larvae), and both woody and non-woody emergent vegetation. A single Canada goose egg (Egg sample number 7) was found impressed into wet soil on the margin of this marsh. This egg may have been a dump egg, or an egg flooded out of an unlocated nest? This egg was clearly already addled before being collected, so no attempt was made to incubate it. The whole-egg selenium content was 9.3 ug/g dry-weight basis. Service Idaho staff revisited this site May 28<sup>th</sup> and collected a sandhill crane egg (Egg sample number 20). This crane egg was at an advanced stage of incubation upon collection and therefore did not require artificial incubation. This egg yielded an advance stage live-normal embryo.



The whole-egg selenium content was 18 ug/g dry-weight basis. Finally, this site was revisited June 20<sup>th</sup>. A mallard nest was discovered in woody emergent vegetation and when the hen flushed she kicked all but one of the eggs out of the nest and into the water of the marsh. Therefore the entire 8-egg clutch was salvaged (Egg sample numbers 23–30) along with a single egg (Egg sample number 22) found underwater on the marsh bottom below the mallard nest. The 8-egg clutch did not require artificial incubation as the eggs were already at an advanced stage of incubation. All eight eggs yielded advanced stage live-normal embryos. Whole-egg selenium content of eggs in this clutch varied from 9.6 to 16 ug/g dry-weight basis. The egg from the marsh bottom was undeveloped and had a whole-egg selenium content of 8.5 ug/g dry-weight basis.

Aquatic macroinvertebrates were so abundant at this marsh that two samples were collected. A sample of adult dragonfly contained 54 ug/g selenium dry-weight basis, and a sample of mosquito larvae contained 788 ug/g selenium dry-weight basis. This site was unexpectedly sparsely populated with breeding waterbirds considering the prime quality of the habitat. However, the selenium content of the mosquito larvae at this site, the most abundant aquatic invertebrate, was so high that it likely would induce immediate acute selenosis in any waterbirds feeding to any substantial extent on that food chain (*cf.* Heinz 1996) and would probably inhibit such birds from coming into breeding condition at this site (*cf.* Ohlendorf 1989: see discussion for American coot failure to come into breeding condition at Kesterson where foodchain aquatic invertebrates topped out at about 400 ug/g selenium dry-weight basis). With this in mind, it is interesting to note that the only waterbird nests located at this site were for wide-ranging species (geese, cranes, mallards) whose egg selenium contents suggest that they were foraging largely off-site.



Photo 35 – Conda Marsh, just downstream of a large waste shale pile (dark triangle in upper center of photo). This is the site where water sample no. 24 and egg samples 7, 20, and 22–30 were collected. This photo was taken in May, compare to Photo 36 below taken in June.



Photo 36 – Conda Marsh, showing sampling location for mosquito larvae that contained 788 ug/g selenium dry-weight basis (where researcher is standing).



Photo 37 – A potential additional concern at the Conda Marsh site was the presence of highly corroded drums of unknown origin and unknown contents.



Water sample number 25 was collected from Montgomery Watson sampling station number 71 (Conda Mine NL4 Pond; 151 ug/L waterborne selenium in fall, 1997). Waterborne selenium was 227 ug/L. A predated mallard nest was located here (see Photos 5 and 6). Seven unincubated eggs were salvaged (Egg sample numbers 8–14) and successfully set in the holding incubator. All seven eggs ultimately yielded advanced stage live–normal embryos. Whole–egg selenium content of the eggs ranged from 11–14 ug/g dry–weight basis. A partial carcass of an adult mallard was also salvaged yielding a breast muscle sample that contained 13 ug/g selenium dry–weight basis.

Photo 38 – Montgomery Watson 1997 water sampling station no. 71, Conda Mine NL4 Pond. Note waste shale terraces (black bars in upper center of photo) that drain directly into the pond (shoreline on bottom of this photo). This was the site of water sample no. 25, and egg samples 8–14.



Water sample number 26 was collected from a vernal flooded natural depression located about 0.9 km northwest of Conda Mine NL4 Pond. Several dabbling ducks flushed from this site upon our approach. No avian eggs were collected. No photos were taken. Our guide from Conda Mine referred to this depression as “Grace Pond”, but it is not labeled as such on USGS topo maps. Waterborne selenium was 2.5 ug/L. A revisit to this site in June confirmed that “Grace Pond” is an ephemeral vernal wetland, as it was nearly dry.

Water sample number 27 was collected from the Conda Mine current (active) tailings reservoir. Waterborne selenium was 8.7 ug/L. This reservoir receives substantive use by waterbirds. Tens to hundreds of eared grebes, dabbling ducks, American coots, and yellow-headed blackbirds were all observed at this site. In addition, June 20<sup>th</sup>, two dead American white pelicans (*Pelecanus erythrorhynchos*) were recovered from the shoreline (Photo 39). One of the dead pelicans was banded with a green wrap-around color band on the left leg and a standard Service aluminum band (no. 519-70228) on the right leg. Based on a band recovery report from the Migratory Bird Banding Lab in Laurel, Maryland, this pelican had been banded as a nestling July 24, 1997, at a breeding colony in Nevada. No avian eggs were collected in May, but upon revisiting this site on June 20<sup>th</sup> 14 American coot eggs were collected (Egg sample numbers 35-48) and seven yellow-headed blackbird eggs were collected (Egg sample numbers 31-34 and 49-51). Nine of the American coot eggs were successfully set in the holding incubator, ultimately yielding seven advanced stage live-normal embryos, one live-abnormal embryo (malformed toes), and one early stage dead-unassessable embryo. The other five American coot eggs failed to successfully initiate development in the holding incubator (*i.e.*, were addled). The whole-egg selenium content of these American coot eggs ranged from 10-16 ug/g dry-weight basis. Only one yellow-headed blackbird egg was successfully set in the holding incubator and ultimately (at



U.C. Davis) was incubated to an advanced stage of development yielding a live-normal embryo. Four of the eggs were early stage (1–4 days of incubation) dead-unassessable embryos and two eggs did not develop at all (addled). The whole-egg selenium content of these blackbird eggs ranged from 12–19 ug/g dry-weight basis. Both the coots and blackbirds were nesting in beds of cattails and it was clear that the coots were early in their nesting chronology as several freshly constructed, yet empty, nesting platforms were located. Thus, Service Idaho staff made a supplemental visit to this site on June 30<sup>th</sup> and collected an additional six American coot eggs (Egg sample numbers 68–73). These eggs were shipped (overnight parcel post) directly to California and no attempt was made to artificially incubate any of them. All of these eggs were either unincubated or incubated to less than 2 days of development when processed and examined in California. Thus, none yielded assessable embryos. The whole-egg selenium content of these supplementally sampled eggs ranged from 12–15 ug/g dry-weight basis, essentially the same as the earlier sample of American coot eggs.



Photo 39 – One of two dead pelicans recovered at Conda Mine new tailings reservoir. The carcass was too decayed to yield a tissue sample.



Photo 40 – Dead beaver on same shore as dead pelicans. Conda Mine facilities are the white buildings on the far shore.





Photo 41 – One of several cattail beds used by breeding waterbirds at the Conda Mine new tailings reservoir.



Photo 42 – Of additional concern at the Conda Mine new tailings reservoir was the presence of highly corroded drums of unknown origin and content right on the shoreline of the reservoir.

*May 14, 1999:* Following a safety orientation and a meeting/briefing with Wayne Perkins (Smoky Canyon Mine), Wayne led a vehicle tour of Smoky Canyon Mine surface water features that were on our Montgomery Watson list. At the end of the tour Wayne returned to the plant and we commenced our field survey. Wayne cautioned us that, at most, there had been about five bird nests noted at Smoky Canyon surface water sites during the last fifteen years. It was not mentioned what the level of nest-searching effort had been.

Water sample number 28 was collected from Montgomery Watson sampling station number 70 (Smoky Canyon Mine Tailings Pond #1; 10 ug/g waterborne selenium in fall, 1997). This site is more appropriately referred to as a reservoir than as a pond. Water sample no. 28 was collected just downstream from the Roberts Creek diversion basin. Waterborne selenium was 6 ug/L. It is unknown precisely where on this large reservoir the Montgomery Watson fall, 1997, sample was collected. An American coot egg was collected (Egg sample number 16) at the same site as water sample no. 28. It was not successfully set

in the holding incubator and did not yield an assessable embryo. The whole-egg selenium content was 29 ug/g dry-weight basis. This site was revisited on June 22<sup>nd</sup> and another American coot egg was collected (Egg sample number 55) as was a red-winged blackbird egg (Egg sample number 56). The American coot egg did not require artificial incubation as it already contained an advanced stage live-normal embryo. The whole-egg selenium content was 35 ug/g dry-weight basis. The red-winged blackbird egg was successfully set in the holding incubator and ultimately yielded an advanced stage live-normal embryo. The whole-egg selenium content was 12 ug/g dry-weight basis.

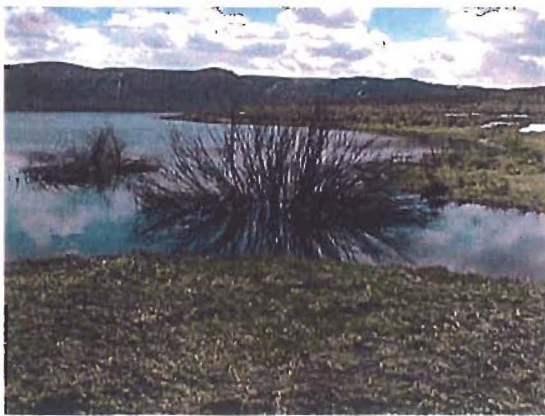


Photo 43 – Smoky Canyon Mine Tailings Reservoir #1, sampling site for water sample no. 28 and egg samples 16 and 55–56.



Photo 44 – American coot sitting on nest at Smoky Canyon Tailings Reservoir #1. Dark image in upper left quadrant of photo is the coot's head.

Water sample number 29 was collected from Smoky Canyon Tailings Reservoir #2. Waterborne selenium was 18 ug/L. Tens to hundreds of eared grebes were observed on the reservoir, but no nesting activity was noted. A Canada goose egg was collected (Egg sample number 17) from a small bare island just offshore. The goose egg was successfully set in the holding incubator and ultimately yielded an advanced stage live-normal embryo. The whole-egg selenium content was 4.6 ug/g dry-weight basis. This site was revisited June



22<sup>nd</sup> and three American avocet (*Recurvirostra americana*) eggs were collected (Egg sample numbers 52–54) from the same island the geese nested on. The goose nest had been predated, with all the eggs except the one collected on May 14<sup>th</sup> lost to predators. The avocet nest was fresh with an incomplete clutch of only three eggs. Due to the high likelihood that the avocet nest would be predated and the high interpretive value of avocet eggs (due to a detailed pre-existing exposure–response curve for selenium; Skorupa 1998) all three avocet eggs were salvaged. One of the avocet eggs was processed immediately and was a fresh unincubated egg (as expected for an incomplete clutch). The other two avocet eggs were successfully set in the holding incubator and ultimately produced advanced stage live–normal embryos. The whole–egg selenium content of these three avocet eggs ranged from 10–24 ug/g dry–weight basis.

Water sample number 30 was collected from Montgomery Watson sampling station number 70 (Smoky Canyon Mine Tailings Pond #1; 10 ug/g waterborne selenium in fall, 1997). This sample was collected about 0.6 km southeast of sample no. 28. Waterborne selenium was 15 ug/L. An American robin egg was collected (Egg sample number 15) on May 14<sup>th</sup> from a nest that still had snow in the nest cup from a snowfall that occurred the night of May 13<sup>th</sup>. This egg did not successfully incubate in the holding incubator and did not yield an assessable embryo. The whole–egg selenium content of the egg was 5.3 ug/g dry–weight basis. This site was revisited on June 22<sup>nd</sup> and three American coot eggs were collected (Egg sample numbers 57–59) as well as two Brewer's blackbird eggs (Egg sample numbers 60 and 61). Of these five eggs, only one of the Brewer's blackbird eggs was successfully incubated artificially to an advanced stage of development and yielded a live–normal embryo. The whole–egg selenium content of the American coot eggs ranged from 48–59 ug/g dry–weight basis. The whole–egg selenium content of both Brewer's blackbird eggs was 23 ug/g dry–weight basis.

Water sample number 31 was collected from an unnamed stream flowing along the eastern edge of Sage Valley (across Sage Valley from Smoky Canyon Mine's Pole Creek waste rock cross-valley fill). Waterborne selenium was 3.5 ug/L. Black-billed magpies (*Pica pica*) were nesting in woody riparian vegetation along this creek and two nests were sampled (Egg sample numbers 18–19). Both of these magpie eggs were successfully set in the holding incubator and both yielded advanced stage live-normal embryos. The whole-egg selenium content of the eggs was 6 ug/g and 5.3 ug/g dry-weight basis.



Photo 45 – Creekside woody vegetation that Black-billed magpies were nesting in. Water sample no. 31 was collected at this site along with egg sample no. 18.

Water sample number 32 was collected from a surface puddle in north-central Sage Valley (east of Pole Creek). This puddle was of interest because of a dead domestic cow nearby. No avian eggs were collected. Waterborne selenium was 3.1 ug/L.

Photo 46 – Dead cow in Sage Valley near site where water sample no. 32 was collected.





Water sample number 33 was collected from an ephemeral surface pool approximately 0.8 km due east of Pole Canyon. No avian eggs were collected. No photos were taken. This ephemeral pool was of interest because a herd of 25–50 American elk (*Cervus canadensis*) were ranging in the vicinity of the pool which was probably a source of drinking water. Waterborne selenium was 5 ug/L.



Photo 47 – Elk pasture downstream from Smoky Canyon Mine Pole Creek cross valley fill (upper center of photo). Water sample no. 33 was collected near here.

*May 21, 1999:* Service Idaho staff returned to the Woodall Spring area to collect additional water samples.

Water sample number 34 was collected from drainage coming off of Woodall Mountain about 0.6 km south of Woodall Spring (the site for water samples 20 and 35 -- see above). No avian eggs were collected. Waterborne selenium was 2.9 ug/L, a value consistent with samples 20 (2.5 ug/L) and 35 (2.3 ug/L).

Water sample number 35 was a replicate sample from Woodall Spring and was described above in the narrative for sample no. 20.

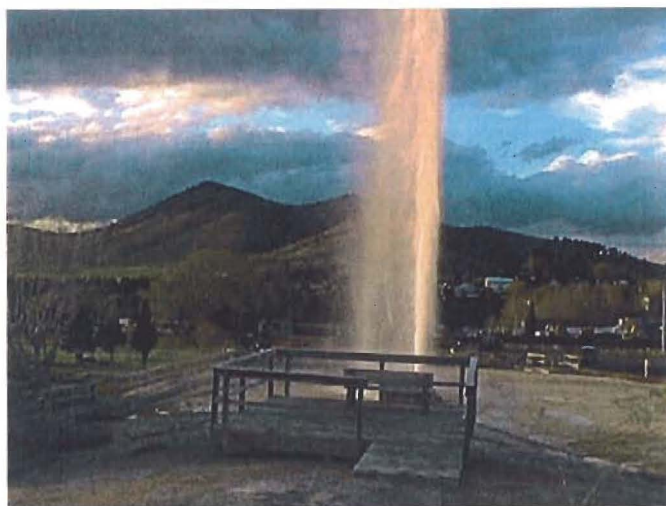
Water sample number 36 was collected from a pond approximately 0.5 km north of Woodall Spring. No avian eggs were collected. No photos were taken. Waterborne selenium was 2.7 ug/L.

Water sample number 37 was collected from Lower Slug Creek spring pond. No avian eggs were collected. No photos were taken. Waterborne selenium was 2.6 ug/L.

There was one other incidental water sample collected in May as follows:

Water sample number 00 was collected from the run-off gutter at the Soda Springs Geyser (in downtown Soda Springs) immediately following a Geyser eruption. This water had a strong sulfurous odor which intrigued our curiosity, because selenium is often found in association with sulfur. No avian eggs were collected, although killdeer were nesting along a ditch which received the Geyser drainage. Waterborne selenium was 2.2 ug/L

Photo 48 – Soda Springs Geyser.  
Location of water sample no. 00.



*June 20-24, 1999:* Most site visits during this week were return visits to sites initially surveyed in May. These revisits were specifically aimed at obtaining avian eggs from sites that had already been sampled for water, especially those sites that yielded highly contaminated water samples ( $>5$  ug/L). These egg collections have already been described above in the narratives for the water samples.

Only one water sample collected in June was analyzed for selenium:

Water sample number 38 was collected from Enoch Valley Mine's South Pond and was described above in the narrative for the initial May visit to South Pond.

In addition, only one avian egg collected in June has not already been described:

Egg sample number 62 was collected June 23<sup>rd</sup> from the south side of Blackfoot River Road adjacent to the Stateland Creek crossing. This site is downstream from the Ballard Mine. The sample was from a killdeer nest on a small patch of gravel. This was the only egg not collected from one of the water sampling sites and the whole egg selenium content was 5.3 ug/g dry-weight basis.

Only one new mine, the Gay Mine, was visited during June. On June 21<sup>st</sup>, and accompanied by Dan Christopherson, two sites associated with the Gay Mine were visited.

One of the sites visited was Montgomery Watson sampling station 56 (Gay Mine A-12 Lake; 100 ug/L waterborne selenium in fall of 1997). Killdeer and spotted sandpiper were present at this site, but no avian eggs were sampled. A sample of the source water draining into the Lake was collected, but this sample (and



the other water samples collected during the Gay Mine site visits) was accidentally disposed of before it had been analyzed, so no waterborne selenium value was obtained.

Photo 49 – Gay Mine A-12  
pit lake, Montgomery Watson  
1997 water sampling station  
no. 56



The other site visited was a pit lake of uncertain identity, although it was thought to be the Gay Mine JD Lake. At this site a substantive die-off of Tiger Salamanders (*Ambystoma tigrinum*), mostly larval salamanders, was discovered. A minimum of 152 carcasses were counted along the shoreline on the shallow end of this pit lake. Two of the least decomposed dead larval salamanders were collected, one morbid, but still living larval salamander was collected, and one dead adult salamander was collected. None of these samples has been analyzed to date. No avian eggs were collected at this site. The water sample collected at this site was accidentally disposed of prior to being analyzed for selenium (as described above for the A-12 pit lake). Unlike most of the pit lakes/ponds visited during this survey, the JD (?) Pit Lake had a fairly well developed shallow photic zone on one end of the lake that supported vigorous algal mats. However, there was as yet no development of typical shallow marsh emergent vegetation and no waterbirds were observed using this lake.



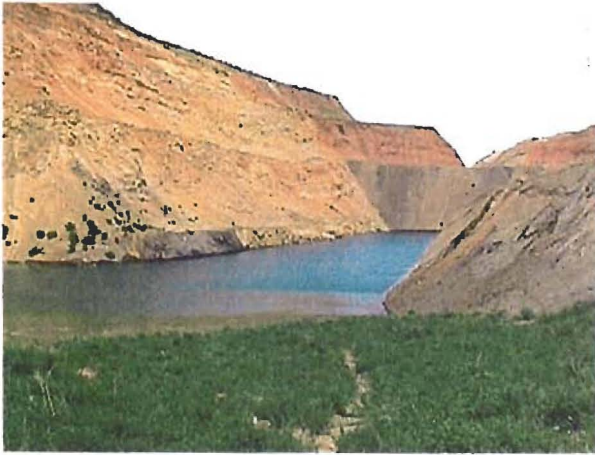


Photo 50 – Gay Mine JD (?) Pit Lake.



Photo 51 – Dead larval Tiger Salamanders along shore of shallow end of the Gay Mine JD (?) Pit Lake.

Other miscellaneous samples collected during June included:

An unidentified species of garter snake (*Thamnophis spp.?*) was collected at Montgomery Watson sampling station number 21 (Dry Valley Mine Pit Dewatering Pond; 113 ug/L waterborne selenium in fall, 1997).

An unidentified species of garter snake was also collected from Montgomery Watson sampling station number 43 (Wooley Valley Mine Upper Angus Creek Reservoir; 1.5 ug/L waterborne selenium in fall, 1997).

Two Northern Leopard Frogs (*Rana pipiens*) were collected from Montgomery Watson sampling station number 43 (Wooley Valley Mine Upper Angus Creek Reservoir; 1.5 ug/L waterborne selenium in fall, 1997).

All data for water and avian egg samples presented above in narrative format, and additional data such as GPS coordinates are summarized in Table 1. GIS mapping of all water and avian egg sampling locations is illustrated in Figure 4.

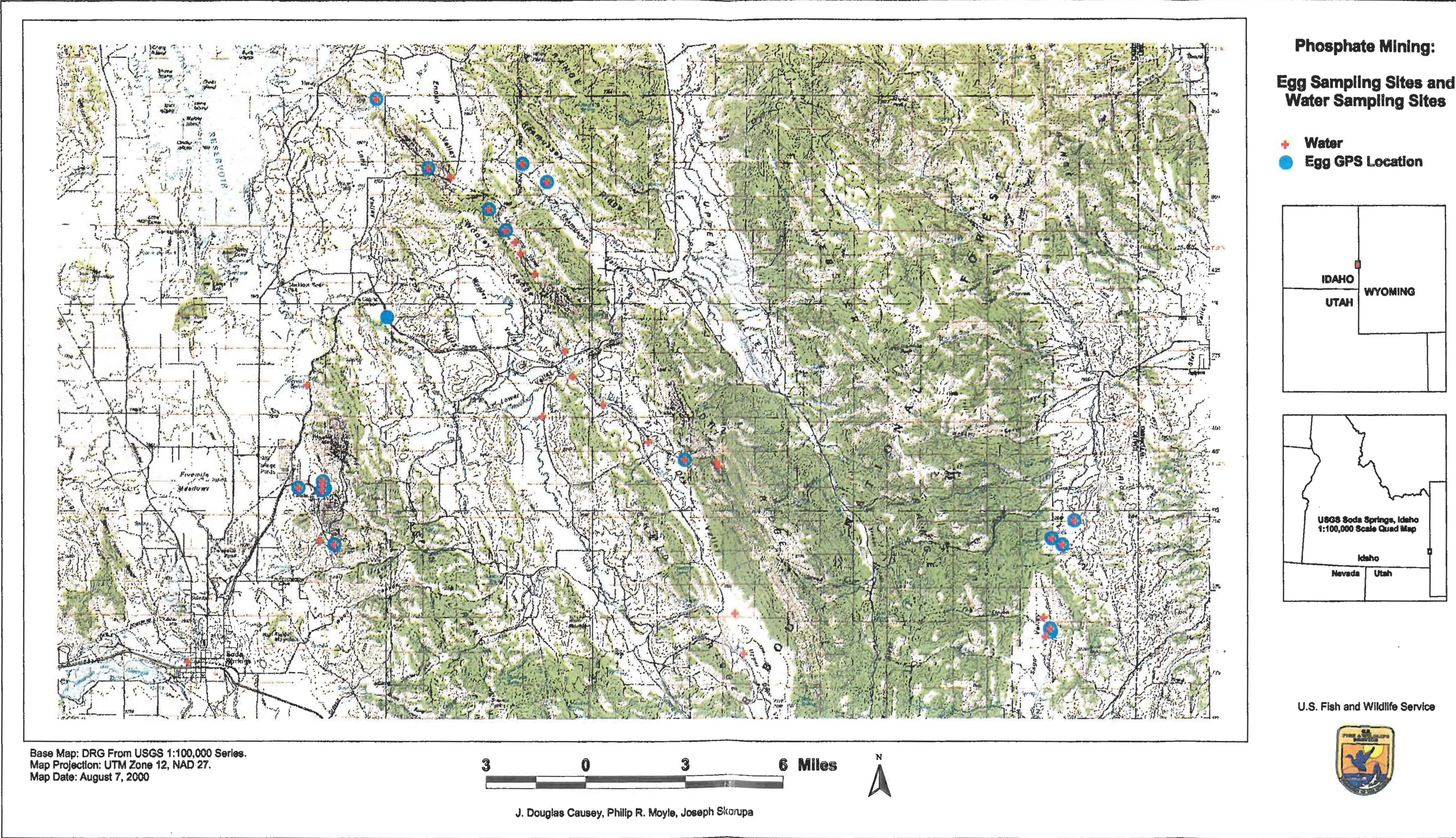


Location Description	GPS Longitude	GPS Latitude	Water Sample #	Water Se (ug/L)	Date	Digital Images	Notes	Egg Sample #	Species	Egg ID	Egg Se (ug/g, dw)	Embryo Status	Date Collected	Digital Images	Notes
Soda Springs Geyser	-111 38 28	42 39 43	000	2.2	05/13/99	0.8 - 0.14	w/Jeff Jones, USFS								
Beaver Pond 0.5 mi E of R Allen Ranch & Slug Creek Rd	-111 22 07	42 48 92	001	2.5	05/11/99	2.7	w/Jeff Jones, USFS								
Roadside Pond near Chicken Creek, NW Dry Valley	-111 21 60	42 48 19	002	58	05/11/99	2.9	w/Jeff Jones, USFS								
Maybe Creek Horse Pasture, Dry Valley	-111 19 97	42 45 21	003	803	05/11/99	2.10, 2.12	w/Jeff Jones, USFS								
Maybe Canyon Spring adjacent to Maybe Creek	-111 17 54	42 44 70	004	716	05/11/99	2.15 - 2.17	w/Jeff Jones, USFS								
Seep Water from toe of Maybe Canyon Cross-Valley Fill	-111 17 45	42 44 57	005	1,394	05/11/99	2.15 - 2.17	w/Jeff Jones, USFS								
Maybe Canyon lower sedimentation pond on Maybe Creek	-111 18 87	42 44 74	006	207	05/11/99	None	w/Jeff Jones, USFS	001	American Robin	Robbo	8.7	12d, LN	05/11/99	2 23	clutch = 1; incubator egg
Viet Pasture near Champ Mine, Upper Dry Valley	-111 18 50	42 39 70	007	4.1	05/11/99	None	w/Jeff Jones, USFS								
Seep near Champ Mine Pit	-111 18 83	42 40 74	008	6.0	05/11/99	3.6	w/Jeff Jones, USFS								
Reservoir on S end of Little Long Valley (Upper Angus Creek); M-W 1997 site # 43	-111 24 01	42 49 59	009	22	05/12/99	None									
Sediment Basin at E base of Haul Rd, South-Central Little Long Valley (Angus Creek)	-111 24 53	42 50 13	010	4.2	05/12/99	None									
Sediment Basin at E base of Haul Rd, North-Central Little Long Valley (Angus Creek)	-111 24 71	42 50 42	011	4.4	05/12/99	3.13									
Drainage pond W side of Haul Rd, N Little Long Valley (Angus Creek)	-111 25 06	42 50 71	012	7.3	05/12/99	None	Belted Kingfisher present	074	American Robin	AMRO12A	5.9	5d, DN	06/24/99	None	clutch = 3; Egg cooked in incubator
Surface Puddle Near Montgomery-Watson 1997 site # 41	No Data	No Data	013	4.1	05/12/99	None	TBS, R43E, Section 33	002	Sandhill Crane	SACR001 (A)	5.3	added	05/12/99	3.14 - 3.17	clutch = 2; incubator egg
Sandhill Crane Nesting Pool, NW and Little Long Valley	-111 25 87	42 51 26	014	77.2	05/12/99	None	Brassfield Photograph	021	Sandhill Crane	SACR004 (B)	7.2	>20d, LN	06/01/99	None	Collected by Rob Brassfield
(continuation)															
Flooded drainage area (pond) near entrance road to Agrum, Wooley Ridge	-111 22 95	42 47 57	015	230	05/12/99	None	Site was dry during June visit								
Solutia West Pond, Rasmussen Valley	-111 24 48	42 52 45	016	68	05/12/99	4.2	w/Mike Vice	003	Sandhill Crane	SACR002	4.2	added	05/12/99		clutch = 2; incubator egg
Beaver Pond on Little Blackfoot River N of Wooley Ridge	-111 29 69	42 54 11	017	3.8	05/12/99	4.15	w/Mike Vice	004	Canada Goose	CAG0001	3.1	18d, LN	05/12/99	4 15	clutch = 5; incubator egg
S Enoch Valley Beaver Pond	-111 27 01	42 52 09	018	4.5	05/12/99	None									
Henry Pond; Montgomery-Watson 1997 site # 25	-111 27 82	42 52 32	019	9.7	05/12/99	4.16		005	Killdeer	KILL001	10	17d, LN	05/12/99	None	clutch = 4; incubator egg
Woodall Spring near Solutia asphalted Haul Rd	-111 32 10	42 48 65	020	2.5	05/12/99	None	Detritus H2O sample # 021								
(continuation)							see above								
Conda E (Old) Tailings Pond (puddle within old pond trace)	-111 31 55	42 44 15	022	307	05/13/99	5.3 - 5.4	w/???, Site was dry during June visit	008	Canada Goose	CAG0002	6.2	16d, LA	05/13/99	5.1 - 5.2	clutch = 7; very close to water site #22; incubator egg, slightly reduced lower bill
Conda E (Old) Tailings Pond (second puddle within old pond trace)	-111 31 54	42 44 04	023	112	05/13/99	5.5	w/???, Site was dry during June visit								
Conda Marsh (large marshy area on S end of (Old) Tailings Pond)	-111 31 58	42 43 91	024	150	05/13/99	5.8, 9.21	w/, Flooded during June visit	007	Canada Goose	CAG0003	5.9	added	05/13/99		dump egg (?) found impressed into wet soil
(continuation)								020	Sandhill Crane	SACR003	16	>15d, LN	05/28/99		clutch = 2; sibling egg pipping
(continuation)								022	Mallard	OSCM001F	8.5	Fresh	05/20/99		clutch = 8 + 1 on marsh bottom near nest - this egg; processed at coll.
(continuation)								023	Mallard	OSCM001A	11	22d, LN	06/20/99		processed upon collection
(continuation)								024	Mallard	OSCM001B	11	24d, LN	05/20/99		Dragonfly adult from this site = 54 ppm Se, dwr, processed at coll.
(continuation)								025	Mallard	OSCM001C	16	23d, LN	05/20/99		Mosquito larvae composite from this site = 788 ppm Se, dwr, processed at coll.
(continuation)								026	Mallard	OSCM001D	11	23d, LN	06/20/99		Above invert data for 06/20/99; processed upon collection
(continuation)								027	Mallard	OSCM001E	10	23d, LN	06/20/99		processed upon collection
(continuation)								028	Mallard	OSCM001F	9.8	24d, LN	06/20/99		processed upon collection
(continuation)								029	Mallard	OSCM001G	8.8	24d, LN	06/20/99		processed upon collection
(continuation)								030	Mallard	OSCM001H	11	24d, LN	05/20/99		processed upon collection
(continuation)								009	Mallard	05001A	14	23d, LN	05/13/99	5 10	All eggs recovered from depredated nest, all incubator eggs
(continuation)								010	Mallard	05001C	13	18d, LN	05/13/99	5 10	Breast muscle from depredated adult = 13 ppm Se, dwr
(continuation)								011	Mallard	05001D	12	24d, LN	05/13/99	5 10	
(continuation)								012	Mallard	05001E	12	23d, LN	05/13/99	5 10	
(continuation)								013	Mallard	05001F	12	23d, LN	05/13/99	5 10	
(continuation)								014	Mallard	05001G	11	23d, LN	05/13/99	5 10	
Grace Pond (Flooded Natural depression)	-111 31 84	42 42 60	026	2.5	05/13/99	None	w/???, possibly dry in June	035	American Coot	AC1A	14	15d, LN	06/20/99	10 4	Incubator egg
Conda W (New) Tailings (Recycling/Slurry) Reservoir	-111 32 40	42 43 96	027	8.7	05/13/99	5.17 - 6.6, 10.1 - 10.2	Banded Dead White Pelican recovered	036	American Coot	AC1B	13	12d, LN	06/20/99	10 4	Incubator egg
(continuation)								037	American Coot	AC2AFTH	16	7d, LN	06/20/99	10 4	Incubator egg
(continuation)								038	American Coot	AC2BFTH	12	20d, LA	06/20/99	10 4	Curly toe; Not FTH; Incubator egg
(continuation)								039	American Coot	AC3A	10	10d, LN	06/20/99	10 4	Incubator egg
(continuation)								040	American Coot	AC3B	13	14d, LN	06/20/99	10 4	Incubator egg
(continuation)								041	American Coot	AC4A	12	added	06/20/99	10 4	Incubator egg
(continuation)								042	American Coot	AC4B	13	added	06/20/99	10 4	Incubator egg
(continuation)								043	American Coot	AC5A	16	added	06/20/99	10 4	Incubator egg
(continuation)								044	American Coot	AC5B	16	added	06/20/99	10 4	Incubator egg
(continuation)								045	American Coot	AC5C	14	added	06/20/99	10 4	Incubator egg
(continuation)								046	American Coot	AC5D	14	5d, DU	06/20/99	10 4	Incubator egg
(continuation)								047	American Coot	AC6A	11	22d, LN	06/20/99	10 4	Incubator egg
(continuation)								048	American Coot	AC6B	8d, LN	06/20/99	10 4	Incubator egg	
(continuation)								031	Yellow-headed Blackbird	YHA3	15	4d, DU	06/20/99	10 4	clutch = 3; incubator egg
(continuation)								032	Yellow-headed Blackbird	YHB4	19	Late, LN	06/20/99	10 4	clutch = 4; incubator egg
(continuation)								033	Yellow-headed Blackbird	YHC4	16	added	06/20/99	10 4	clutch = 4; incubator egg
(continuation)								034	Yellow-headed Blackbird	YHD4	14	3d, DU	06/20/99	10 4	clutch = 4; incubator egg
(continuation)								049	Yellow-headed Blackbird	YH10A	12	1d, DU	06/20/99	10 4	clutch = 3; incubator egg
(continuation)								050	Yellow-headed Blackbird	YH10B	13	1d, DU	06/20/99	10 4	Incubator egg
(continuation)								051	Yellow-headed Blackbird	YH10C	14	Fresh	06/20/99	10 4	Incubator egg
(continuation)								068	American Coot	ACAD1A	13	Fresh	06/30/99		Collected by Rob Brassfield
(continuation)								069	American Coot	ACAD1B	14	Fresh	06/30/99		Collected by Rob Brassfield
(continuation)								070	American Coot	ACB01A	12	Fresh	06/30/99		Collected by Rob Brassfield
(continuation)								071	American Coot	ACB01B	13	Fresh	06/30/99		Collected by Rob Brassfield
(continuation)								072	American Coot	ACC01A	14	Fresh	06/30/99		Collected by Rob Brassfield
(continuation)								073	American Coot	AMC005	16	1d, DU	06/30/99		Collected by Rob Brassfield
Smoky Canyon Tailings Reservoir # 1 near Roberts Creek, Montgomery-Watson 1997 site # 70	-111 05 62	42 42 72	028	6.0	05/14/99	7.4		018	American Coot	AMCO	29	Fresh	05/14/99	7.1 - 7.4	clutch = 1; incubator egg
(continuation)								055	American Coot	SMAC3A	35	21d, LN	06/22/99		processed upon collection; 1 of 2 in nest, sib hatching
(continuation)								056	Red-winged Blackbird	RW1A	12	Late, LN	06/22/99		incubator egg
Smoky Canyon Tailings Reservoir # 2	-111 04 83	42 43 19	029	18	05/14/99	7.5	Water sampled at small island	017	Canada Goose	CAG0004	4.8	12d, LN	05/14/99	7.5	clutch = 2; incubator egg
(continuation)								052	American Avocet	03SM001A	10	18d, LN	06/22/99	7.5	clutch = 3; incubator egg
(continuation)								053	American Avocet	03SM001B	24	Fresh	06/22/99		processed upon collection
(continuation)								054	American Avocet	03SM001C	14	14d, LN	06/22/99		Incubator egg
Smoky Canyon Tailings Reservoir # 1	-111 05 25	42 42 58	030	15	05/14/99	8.18, 8.21	Water sampled in a willow tree cove	015	American Robin	AMRO 70 001	5.3	5d, DU	06/22/99	6.20	clutch = 4; incubator egg; eggs cold, snow inside nest cup
(continuation)								057	American Coot	SMAMC02A	48	added	06/22/99		clutch = 3; incubator egg
(continuation)								058	American Coot	SMAMC02B	56	5d, DU	06/22/99		incubator egg
(continuation)								059	American Coot	SMAMC02C	59	added	06/22/99		incubator egg
(continuation)								060	Brewer's Blackbird	BR1A	23	added	06/22/99		incubator egg
(continuation)								061	Brewer's Blackbird	BR1B	23	Mid, LN	06/22/99		incubator egg
Eastside Sage Valley Creek (unnamed on USGS Sage Valley 7.5 Degree Quadrangle map)	-111 05 68	42 40 37	031	3.5	05/14/99	7.15		018	Black-billed Magpie	MAGP001	6.0	10d, LN	05/14/99	7.15	clutch = 8; nest in willow on small tuft in middle of the creek; All egg
(continuation)								019	Black-billed Magpie	MAGP002	5.3	9d, LN	05/14/99		clutch > 5; nest just downstream from nest 001; All egg
N-Central Sage Valley Pasture (rest of Pole Creek)	-111 05 83	42 40 17	032	3.1	05/14/99	7.16	Surface puddles near dead cow	062	Killdeer	136R001A	5.3	Fresh	06/23/99		clutch = 4; cooked in incubator
Sage Valley ephemeral surface pool ca. 0.5 mi due E of Pole Canyon	-111 05 80	42 40 07	033	5.0	05/14/99	None		063	American Coot	AMCO SP1A	80	added	06/23/99		clutch = 2; cooked in incubator
Stream from Woodall Mtn ca. 0.4 mi. S of Woodall Spring	No Data	No Data	034	2.9	05/21/99	None	collected by Rob Brassfield, which of two streams??	064	American Coot	AMCO SP1B	73	added	06/23/99		FTH egg, in nest with 4 LN nestlings; cooked in incubator
Pond ca. 0.3 mi N of Woodall Spring	No Data	No Data	036	2.7	05/21/99	None	collected by Rob Brassfield	065	Red-winged Blackbird	RW1SP	13	No Dev	06/23/99		clutch = 1; cooked in incubator
Lower Slug Creek Spring Pond	-111 23 73	42 45 87	037	2.6	05/21/99	None	collected by Rob Brassfield	066	Red-winged Blackbird	RW6BSP2A	23	Fresh	06/23/99		clutch = 1; dump egg (?)
Blackfoot River Road (gravel patch across from Statedale Creek)	-111 29 27	42 48 44						067	Brown-Headed Cowbird	BHCBSP1A	4.9	Fresh	06/23/99		
Solutia South Pond (Rasmussen Valley)	-111 23 60	42 51 96	038	66	06/23/99	4.7	collected at Coot nest								
(continuation)															
(continuation)															
(continuation)															
(continuation)															



FIGURE 4.

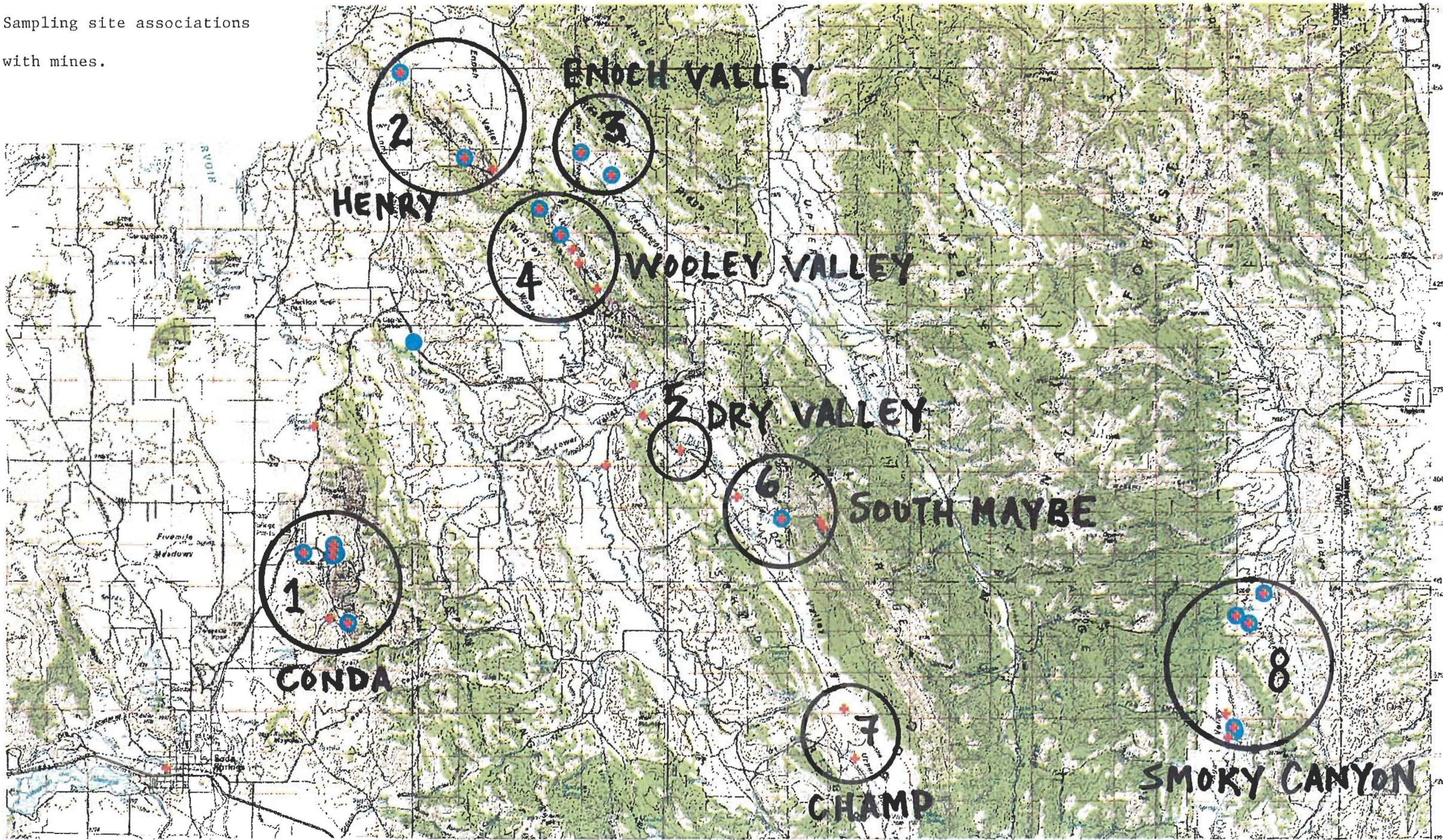
Bird Egg And Water Sample Sites, in Phosphate Mining Areas, Near Soda Springs, Idaho.





# Bird Egg And Water Sample Sites, in Phosphate Mining Areas, Near Soda Springs, Idaho.

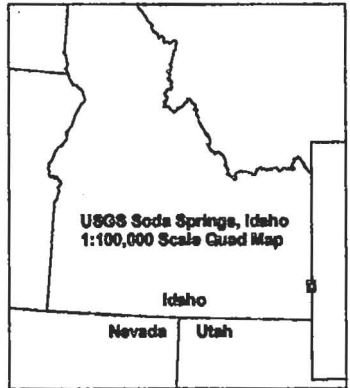
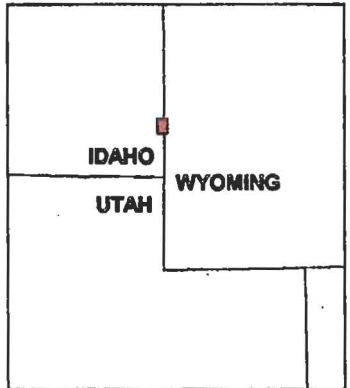
FIGURE 5. Sampling site associations with mines.



## Phosphate Mining:

### Egg Sampling Sites and Water Sampling Sites

- Water
- Egg GPS Location



U.S. Fish and Wildlife Service



Base Map: DRG From USGS 1:100,000 Series.  
Map Projection: UTM Zone 12, NAD 27.  
Map Date: August 7, 2000

3 0 3 6 Miles



J. Douglas Causey, Philip R. Moyle, Joseph Skorupa

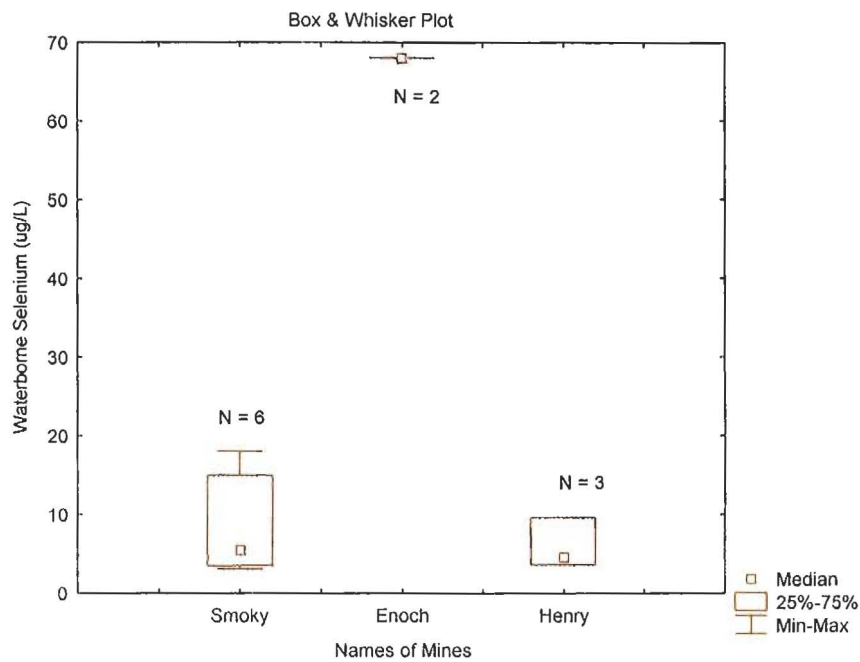


Results by Mines – The samples collected for this survey can be associated with eight former or present phosphate mines, including Conda, Henry, Enoch Valley, Wooley Valley, Dry Valley, South Maybe, Champ, and Smoky Canyon mines (circles 1–8 respectively on Figure 5). However, no avian eggs were collected at the two water sampling sites associated with the Champ mine and the single sampling site associated with the Dry Valley mine. Results summarized here will be restricted to the six mines for which both water and avian eggs were sampled.

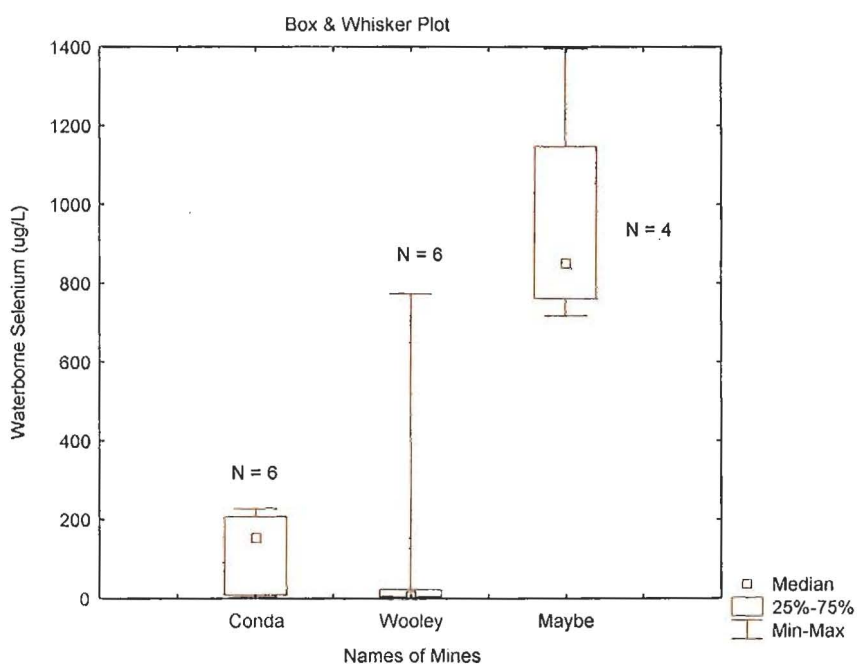
Water Samples – Water samples by mine are illustrated in Figures 6A and 6B. Sample sizes are very limited for all mines, ranging from 2–6 sampling sites. The results can be grouped broadly into two categories, those mines where all measures of waterborne selenium were below 100 ug/L (Smoky Canyon, Enoch Valley, and Henry mines; Figure 6A), and those mines with one or more associated sampling sites that yielded measures of waterborne selenium greater than 100 ug/L (Conda, Wooley Valley, South Maybe mines; Figure 6B). Virtually all mines were associated with at least one sampled downstream surface wetland or impoundment that exceeded 10 ug/L, a value that's 25–50 times normal background values for selenium in freshwater aquatic ecosystems (*e.g.*, Maier and Knight 1994). Henry mine was the exception with a maximum sampled downstream water value of 9.6 ug/L selenium, but only three sites associated with the Henry mine were sampled. Water samples associated with the South Maybe mine were by far the most contaminated (median of 850 ug/L, for four sites sampled). Only one of the four sampling sites associated with the South Maybe mine yielded an avian egg sample during our very limited survey time windows. The best potential avian breeding habitat with waterborne selenium greater than 100 ug/L, based on prior fieldwork with breeding waterbirds, was associated with the Conda mine within the footprint of the inactive “upper” or “old” tailings pond.

Figure 6. Results of water sampling by mines. A: Mines with all samples < 100 ug/L  
B: Mines with some samples > 100 ug/L

A.



B.

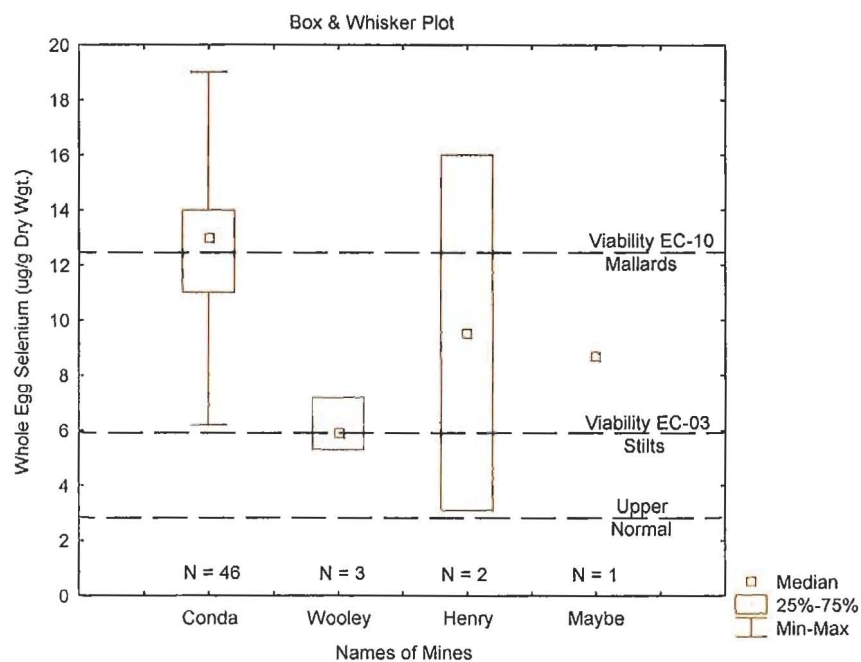




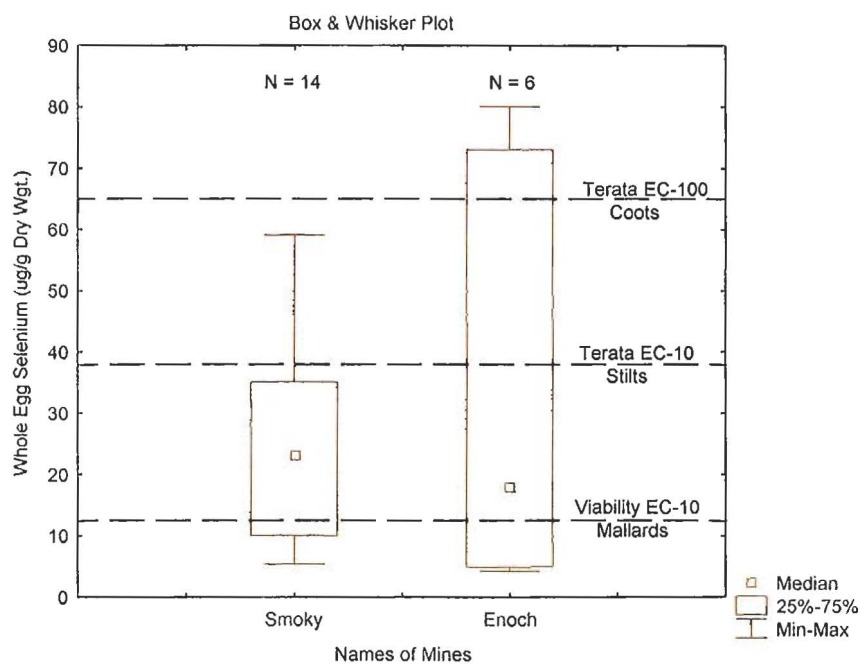
Avian Egg Samples – Avian egg samples by mine are illustrated in Figures 7A and 7B. Sample sizes are highly variable, ranging from 1–46 eggs. The results can be grouped broadly into two categories, those mines where all measures of whole-egg selenium were below 20 ug/g dry weight (Conda, Henry, Wooley Valley, and South Maybe mines; Figure 7A), and those mines with one or more samples that yielded measures of whole-egg selenium greater than 20 ug/g (Enoch Valley and Smoky Canyon mines; Figure 7B). Based on this survey's nonrandom attempt to discover worst-case conditions, the median values for whole-egg selenium associated with every mine (Figures 7A and 7B) easily exceeded the normal background value of 3 ug/g dry weight (Skorupa and Ohlendorf 1991). Likewise, at every mine 50 percent or more of the sampled eggs exceeded the EC-03 effects threshold for egg viability delineated for black-necked stilts (Skorupa 1998, 1999). In other words, at surveyed sites associated with every mine (sampled for avian eggs) more than 50 percent of the eggs had a 3 percent or greater probability of being selenium poisoned based on a level of sensitivity documented for wild black-necked stilts (a large shorebird). At three mines, Conda, Smoky Canyon, and Enoch Valley, 50 percent of the eggs had a 10 percent or greater probability of being selenium poisoned based on a level of sensitivity documented for game-farm mallards in laboratory studies (CH2M HILL 2002). Comparisons between mines are confounded by differences in the species sampled and differences in overall sample sizes. For example, from a comparative perspective, the result for South Maybe mine illustrated in Figure 7A is almost certainly very understated because only one egg was collected and that egg was not from a species of waterbird or shorebird. In fact, of the three mines yielding an associated egg for American robins (Wooley Valley, South Maybe, Smoky Canyon), the sample associated with the South Maybe mine was the most contaminated (Table 1). At sites associated with both the Smoky Canyon and Enoch Valley mines the maximum whole-egg selenium values suggest a high probability of detecting selenium-induced embryo deformities (terata) with consistent sampling.

Figure 7. Results of egg sampling by mines. A: Mines with all samples < 20 ug/g dry wgt.  
B: Mines with some samples > 20 ug/g dry wgt.

A.



B.



Trends in Avian Egg Selenium as a Function of Waterborne Selenium – There is no discernible relationship between the overall median measures of waterborne selenium and the overall median measures of whole-egg selenium for each mine (Table 2; Spearman rank correlation coefficient =  $-0.20$ , N.S.). The lack of a relationship is probably the result of many uncontrolled confounding factors such as: 1) very small sample sizes ( $n = 1-3$ ) associated with some mines for either water, or eggs, or both, 2) differences between mines in species of birds sampled, 3) differing proportions between mines of water samples that were matched with egg samples, 4) poor match in time between when water was sampled and when eggs were ovulated (there are strong seasonal patterns in waterborne selenium; Presser et al., In Prep.), and 5) differences between mines in degree of local residency of breeding birds.

---

Table 2. Median waterborne and whole-egg selenium by mines.

---

Mine	Median H <sub>2</sub> O Se ug/L (n)	Median Whole Egg Se ug/g dry wgt. (n)
Conda	156 (6)	13 (46)
Henry	4.5 (3)	9.6 (2)
Enoch Valley	68 (2)	18 (6)
Wooley Valley	5.9 (6)	5.9 (3)
South Maybe	850 (4)	8.7 (1)
Smoky Canyon	5.5 (6)	23 (14)

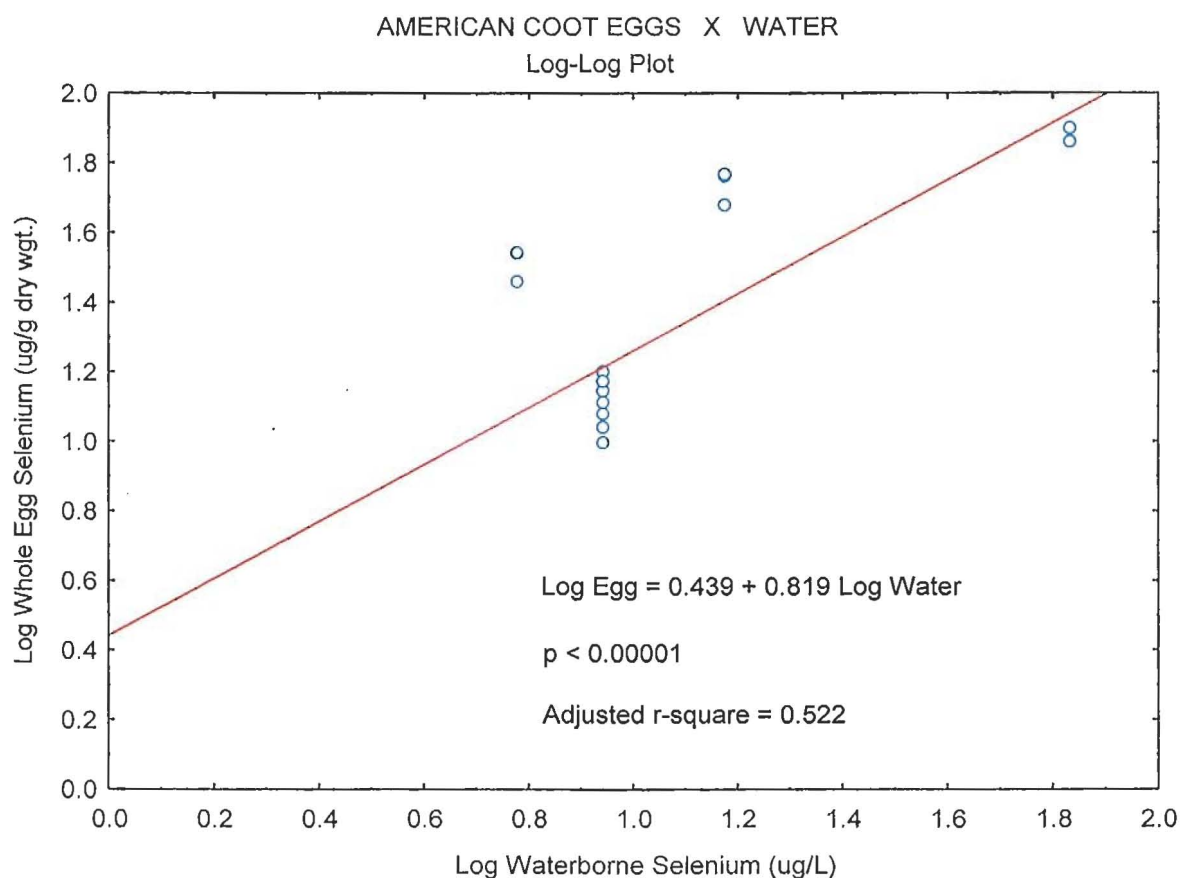
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Eggs of American coots were collected from four locations with matched water samples. For this brief survey the subset of 27 American coot eggs provides



the most controlled set of data for examining water–egg relationships (Figure 8). For these data, waterborne selenium explains about 52% of the variation in whole–egg selenium, and the expected general positive correlation is clearly evident (Figure 8;  $p < 0.00001$ ).

**FIGURE 8.** General correlation between waterborne selenium and whole–egg selenium for American coots. Plot based on 27 data points, many of which are repeat values and therefore are not individually distinguishable in this Figure.



A series of U.S. Geological Survey 7.5 minute topographical maps with greater detail (than Figures 4 or 5) regarding mine–specific sampling locations follows (Figures 9–13).

FIGURE 9. Locations of sampling sites

associated with Conda Mine



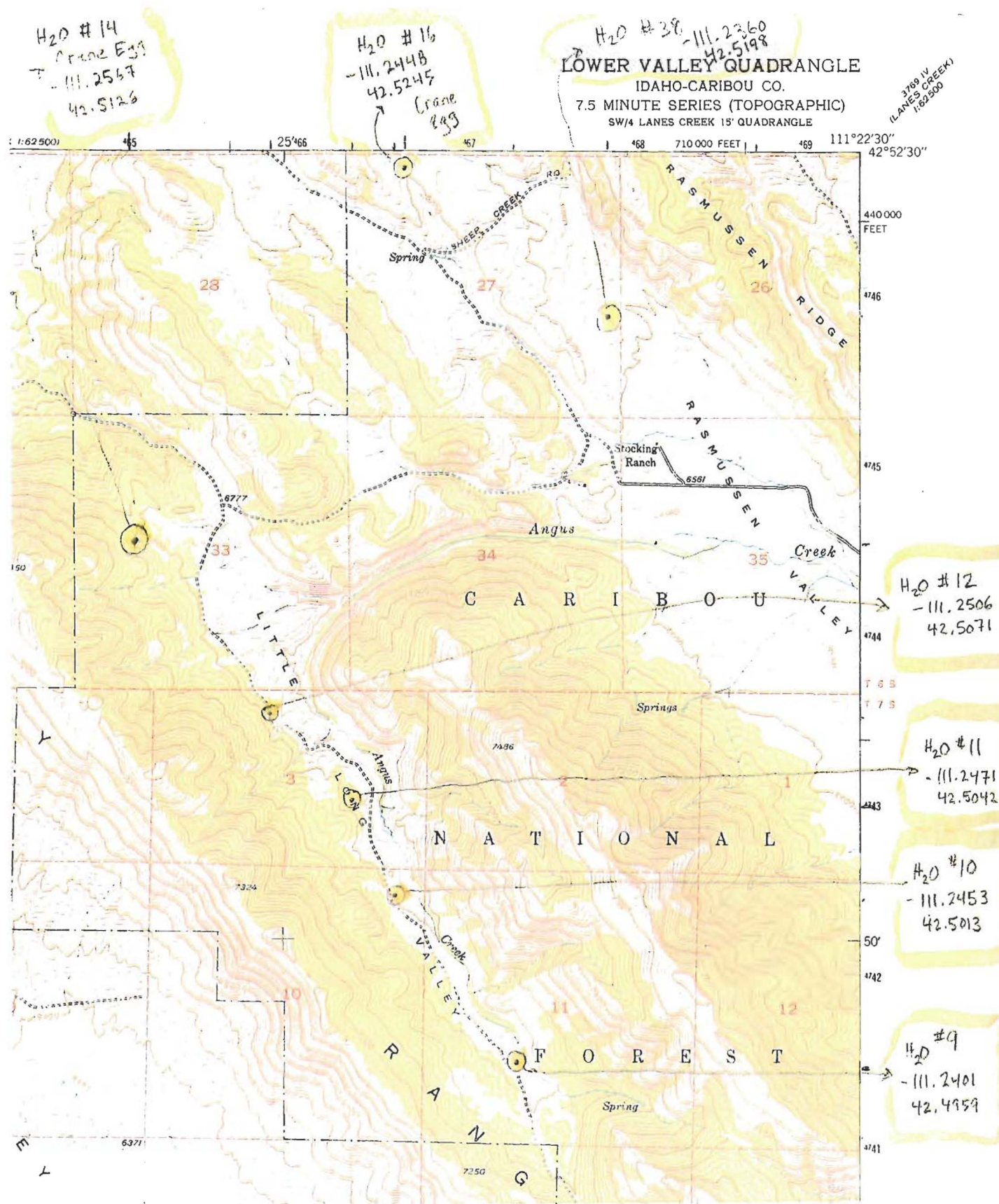


Lower Valley 7.5 minute U.S. Geological Survey topographic map.





FIGURE 11. Locations of sampling sites associated with Enoch Valley and Wooley Valley mines.





Maybe Canyon sites only.





7281 SW  
(DIAMOND FLAT)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

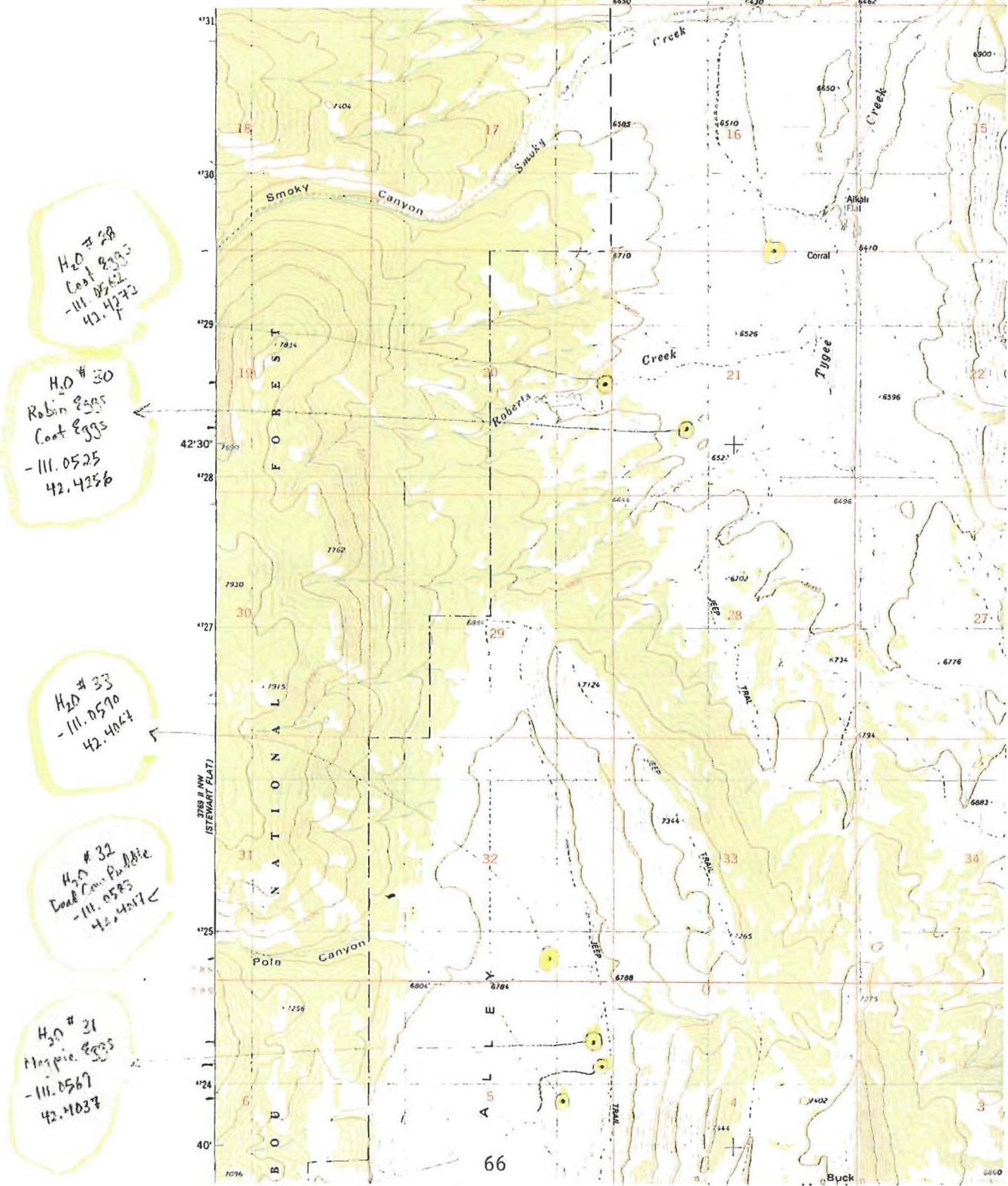
H<sub>2</sub>O # 29  
Goose Egg  
Avocado Egg  
-111.04982  
42.41319

111°07'30"  
42°45'  
760 000 FEET  
(WYO.)

230 000 FEET (WYO.) '93 5' 3759 I  
ALBION E 3N (ALBU)

FIGURE 13. Locations of sampling sites associated with Smoky Canyon mine.

Sage Valley 7.5 minute U.S. Geological Survey topographical map.





Embryo Assessments – A total of 39 assessable embryos were obtained from the 74 eggs sampled for this survey. Artificial incubation was attempted with 53 eggs and this effort produced 29 (74%) of the assessable embryos. Except for American coots and mallards, few embryos were obtained for any given species (Table 3). Artificial incubation was very successful for species, such as mallard, avocet, and killdeer (10 of 11 eggs successfully incubated), that the investigators had prior experience with. Poor success was obtained for species, such as American coot and yellow-headed blackbird (9 of 27 eggs successfully incubated), that the investigators had not worked with previously.

Table 3. Distribution of Assessable Embryos by Species and Outcome.

Species	<u>Assessable Embryos</u>		Unassessable Embryos
	Normal	Abnormal	
American coot	8	1	18
mallard	15	0	1
yellow-headed blackbird	1	0	6
Canada goose	2	1	1
sandhill crane	2	0	2
American avocet	2	0	1
American robin	2	0	1
red-winged blackbird	1	0	2
Brewer's blackbird	1	0	1
black-billed magpie	2	0	0
killdeer	1	0	1
brown-headed cowbird	0	0	1
TOTALS	37	2	35

Abnormal Embryos – Embryos were inspected for non-reversible major structural deformities that are overtly obvious upon superficial external inspection (see Lemly 1993, 1997, for comparable criteria for fish larvae). Nonstructural abnormalities, even though externally visible, such as hydrocephaly, generalized edema, subcutaneous hemorrhaging, and cloudy eyes did not qualify as teratogenic responses for the assessments conducted as part of this survey. The assessment protocol also is not suited for detecting abnormal internal organs or other internal tissues. Thus, the embryo assessments are conservative. What the assessment protocol is aimed at detecting are the severe selenium-induced abnormalities referred to as “monstrosities” in the early literature on selenium toxicity in birds (e.g., Franke and Tully 1936; Franke et al. 1936). Examples of the types of abnormalities the embryos were screened for can be found in the photos presented by Franke and Tully (1935), Carlson (1961), Ohlendorf et al. (1986a), Presser and Ohlendorf (1987), Hoffman and Heinz (1988), Hoffman et al. (1988), Ohlendorf et al. (1988), Ohlendorf (1989), Howard (1989), Bobker (1993), Ohlendorf and Hothem (1995), Ohlendorf (1996), O’Toole and Raisbeck (1998), and Seiler et al. (1999). In practice this amounts to overt deformities of the eyes, bill (beak), and/or limbs.

Two embryos with overt, non-reversible structural deformities were collected during this survey. One was a Canada goose embryo and one was an American coot embryo (Tables 1 and 2). Both embryos were from eggs associated with the Conda mine. The Canada goose embryo was collected early in incubation (estimated to have been incubated for 3 days prior to collection) and subsequently incubated artificially for an additional 13 days. This embryo possessed a slightly reduced lower bill (beak). See Photo 52 below. Hypoplasia (reduction) of the lower bill is reported to be a “distinctive feature” of selenium-induced avian teratogenesis among ducks (O’Toole and Raisbeck 1998). However, the very subtle expression of hypoplasia in this case is either an

indication of a near-threshold selenium effect, or of a non-selenium induced abnormality. The selenium concentration of this goose egg, 6.2 ppm dry-weight basis is clearly elevated (ca. 3–4 times normal), but only slightly relative to known thresholds for teratogenesis. This result could be considered consistent with either a threshold selenium effect or a non-selenium effect. See et al. (1992) reported documentation of deformed Canada goose embryos



Photo 52 – TOP = Normal lower bill of 18-day incubated Canada goose embryo from Little Blackfoot River (Egg No. 004). BOTTOM = Abnormal, slightly reduced (shortened) lower bill of 16-day incubated Canada goose embryo from Conda old tailings pond (Egg No. 6).

from selenium-exposed populations in Wyoming and Utah and also reported that although many studies of Canada goose reproduction have examined embryos, no deformities have been reported from populations not exposed to selenium (e.g., Bellrose, 1980). See et al. (1992) summarized their findings for Wyoming and Utah with the statement: “These results indicate that impaired egg hatchability and teratogenesis might occur in Canada goose populations



with geometric mean concentrations of selenium in eggs as small as 5.5 ug/g (ppm) dry weight.” When results from this Idaho Survey are viewed in light of See et al.’s data from Wyoming and Utah it is clearly most prudent to provisionally consider the abnormal Canada goose embryo as evidence of selenium poisoning (particularly since, as large-bodied herbivores, geese can be expected to be more sensitive to selenium poisoning than any species of bird studied in the lab to date, *cf.* DuBow 1989), while bearing in mind that both the severity of the abnormality observed and the concentration of selenium detected in the egg fall short of providing a clearly definitive case for selenium poisoning.

The abnormal American coot embryo was collected as a freshly laid egg from an incomplete clutch and was artificially incubated for 20 days prior to harvesting and assessment. This embryo possessed malformed feet/toes, and was stunted for its stage of incubation (see Photo No. 53 below). This embryo was assessed at U.C. Davis simultaneously with controlled selenium feeding experiments with chickens, and the U.C. Davis investigator noted that the foot/toe malformations seen in the coot embryo were very similar to foot/toe malformations concurrently being observed in chicken embryos from the selenium feeding study. Carlson (1961) presents photos of chicken embryos affected by experimental selenium exposure that confirm the close similarity with Photo No. 53 below.

However, it has been the first author’s experience with wild dabbling ducks and shorebirds that selenium-induced malformation of limbs rarely occurs without accompanying reduction or absence of eyes and/or malformation of the bill (beak). There are taxonomic differences though, with reduction/absence of eyes being the most common threshold effect in shorebirds, and reduction/malformation of the bill (beak) generally being the most common

threshold effect in dabbling ducks. This coot egg contained 12 ppm selenium dry-weight basis, which would have to be considered, at most, a threshold level of exposure for teratogenesis in coots (Ohlendorf et al. 1986b). Perhaps threshold teratogenic expression in feet/toes is simply taxon-specific to coots (as are threshold teratogenic expression in eyes to shorebirds and bills (beaks) to dabbling ducks). Due to the relatively mild nature of the abnormality (i.e., only one type of anatomical structure involved), and the threshold level selenium exposure of the egg, this embryo also falls short of providing a clearly definitive (slam-dunk) case for selenium poisoning. Once again, however, considering the total weight of evidence it would be very prudent to provisionally consider this embryo to be a case of selenium poisoning (12 ppm *in ovo* selenium is about 10-times the normal background exposure for coots).



Photo 53 – Abnormal American coot embryo collected from the Conda Mine active tailings reservoir (Egg No. 38).

Risk Assessment – Sufficient data for taxon-specific logistic exposure-response curves are now available for four avian taxa, black-necked stilts, American avocets, dabbling ducks (combination of data for mallard, pintail, gadwall, and redhead ducks), and American coots (Ohlendorf et al. 1986b; Skorupa 1998; and Skorupa et al., unpublished data). The taxon specific coefficients for the general logistic model:  $Y = \text{EXP}(b_0 + b_1X) / (1 + \text{EXP}(b_0 + b_1X))$  are as follows:

	$b_0$	$b_1$
STILT	-6.651	0.1158
AVOCET	-6.979	0.0643
DUCKS	-9.303	0.3096
COOTS	-3.148	0.0630

All of the above coefficients are updated from previous publications by including additional unpublished data collected subsequent to cited publication dates. Thus, the coefficients reflect all data available to the authors as of the date of this report. Using the above coefficients, an estimated probability of teratogenesis for every egg can be obtained, even for eggs that did not yield an assessable embryo, based solely on the selenium concentrations measured for each egg. The duck coefficients were applied to goose eggs. The stilt coefficients were used for all other eggs that were not avocet, duck, or coot eggs because the stilt coefficients yield a response curve that is intermediate between the extremes (i.e., species of birds were assumed to be of “average” sensitivity to selenium [like stilts] unless a species-specific curve was available). The resulting teratogenic risk estimates for each egg are presented in Table 4.

Of the 74 eggs collected, 10 contained selenium concentrations high enough to yield estimates of teratogenic risk that exceeded 10% (Table 4). Unfortunately,



**Table 4. Teratogenic Risk Estimates**

Species	Mine	Selenium	Terata	Stilt Risk	Duck Risk	Coot Risk	Avocet Risk
AmRobin	Maybe	8.7	0	0.00353			
AmRobin	Wooley	5.9	0	0.00255			
Sandhill Crane	Wooley	5.3		0.00238			
Sandhill Crane	Wooley	7.2	0	0.00297			
Sandhill Crane	Enoch	4.2		0.00210			
CanGoose	Henry	3.1	0		0.00024		
Killdeer	Henry	16	0	0.00818			
CanGoose	Conda	6.2	1		0.00062		
CanGoose	Conda	9.3			0.00162		
Sandhill Crane	Conda	18	0	0.01029			
Mallard	Conda	8.5			0.00127		
Mallard	Conda	10	0		0.00201		
Mallard	Conda	13	0		0.00508		
Mallard	Conda	16	0		0.01275		
Mallard	Conda	11	0		0.00274		
Mallard	Conda	10	0		0.00201		
Mallard	Conda	9.6	0		0.00178		
Mallard	Conda	9.9	0		0.00195		
Mallard	Conda	12	0		0.00373		
Mallard	Conda	11	0		0.00274		
Mallard	Conda	14	0		0.00690		
Mallard	Conda	13	0		0.00508		
Mallard	Conda	12	0		0.00373		
Mallard	Conda	12	0		0.00373		
Mallard	Conda	12	0		0.00373		
Mallard	Conda	11	0		0.00274		
AmCoot	Conda	14	0			0.09397	
AmCoot	Conda	13	0			0.08874	
AmCoot	Conda	16	0			✓ 0.10525	
AmCoot	Conda	12	1			0.08378	
AmCoot	Conda	10	0			0.07461	
AmCoot	Conda	13	0			0.08874	
AmCoot	Conda	12				0.08378	
AmCoot	Conda	13				0.08874	
AmCoot	Conda	16				✓ 0.10525	
AmCoot	Conda	16				✓ 0.10525	
AmCoot	Conda	14				0.09397	
AmCoot	Conda	14				0.09397	
AmCoot	Conda	11	0			0.07907	
AmCoot	Conda	11	0			0.07907	
Y-HBlackbird	Conda	15		0.00729			
Y-HBlackbird	Conda	19	0	0.01153			
Y-HBlackbird	Conda	16		0.00818			
Y-HBlackbird	Conda	14		0.00650			
Y-HBlackbird	Conda	12		0.00516			
Y-HBlackbird	Conda	13		0.00579			
Y-HBlackbird	Conda	14		0.00650			
AmCoot	Conda	13				0.08874	
AmCoot	Conda	14				0.09397	
AmCoot	Conda	12				0.08378	
AmCoot	Conda	13				0.08874	
AmCoot	Conda	14				0.09397	
AmCoot	Conda	15				0.09947	
AmCoot	Smoky	29				✓ 0.21053	
AmCoot	Smoky	35	0			✓ 0.28010	

**Table 4. Teratogenic Risk Estimates (cont.)**

Species	Mine	Selenium	Terata	Stilt Risk	Duck Risk	Coot Risk	Avocet Risk
R-WBlackbird	Smoky	12	0	0.00516			
CanGoose	Smoky	4.6	0		0.00038		
AmAvocet	Smoky	10	0				0.00177
AmAvocet	Smoky	24					0.00434
AmAvocet	Smoky	14	0				0.00229
AmRobin	Smoky	5.3		0.00238			
AmCoot	Smoky	48				✓ 0.46867	
AmCoo*	Smoky	58				✓ 0.62342	
AmCoot	Smoky	59				✓ 0.63809	
BrBlackbird	Smoky	23		0.01821			
BrBlackbird	Smoky	23	0	0.01821			
B-BMagpie	Smoky	6	0	0.00258			
B-BMagpie	Smoky	5.3	0	0.00238			
Killdeer		5.3		0.00238			
AmCoot	Enoch	80				✓ 0.86867	
AmCoot	Enoch	73				✓ 0.80977	
R-WBlackbird	Enoch	13		0.00579			
R-WBlackbird	Enoch	23		0.01821			
B-HCowbird	Enoch	4.9		0.00227			

1  
marsh  
wren

only 2 of those 10 eggs yielded assessable embryos (as indicated by an entry of a "0" [normal embryo] or a "1" [abnormal embryo] in the terata column of Table 4), and none of the 4 eggs with an estimated teratogenic risk of greater than 50% yielded an assessable embryo. If the survey had succeeded in obtaining assessable embryos from those 4 eggs, the odds of documenting a "slam-dunk" selenium-induced embryo deformity would have been very high (99.6 percent chance).

The teratogenic risk estimates presented in Table 4 predict that for the 39 eggs from which assessable embryos were obtained, there should have been 1.11 abnormal embryos (or a 2.8% rate of teratogenesis); or that the mean number of abnormal embryos observed for multiple replicate samples of 39 embryos was predicted to be 1.11. The actually observed number of abnormal embryos in this survey, two (2), is consistent with the risk assessment predictions (i.e., the observed 2 of 39 is not significantly different from the predicted 1.11 of 39). The teratogenic risk estimates presented in Table 4 predict that for the 35 eggs from which assessable embryos were not obtained, there should have been 4.84 abnormal embryos (or a 13.8% rate of teratogenesis). This higher predicted rate of teratogenesis is reflective of the fact that assessable embryos were not obtained from the most highly contaminated eggs. Thus, overall, for the 74 eggs sampled from the "high-risk" sites surveyed in this study the egg chemistry and species mix yielded a prediction of 5.95 abnormal embryos, or an 8.04% level of teratogenic risk. That level of risk, on a percentage basis, exceeds the level of risk that was documented for California's Kesterson Reservoir in the mid-1980's (Ohlendorf 1989).

Teratogenic risk is only one component of embryo risk from selenium exposure (Skorupa 1999). Controlled experiments have shown that embryo death without teratogenesis is induced at lower concentrations of selenium exposure than embryo death with teratogenesis (the end point measured in this survey).



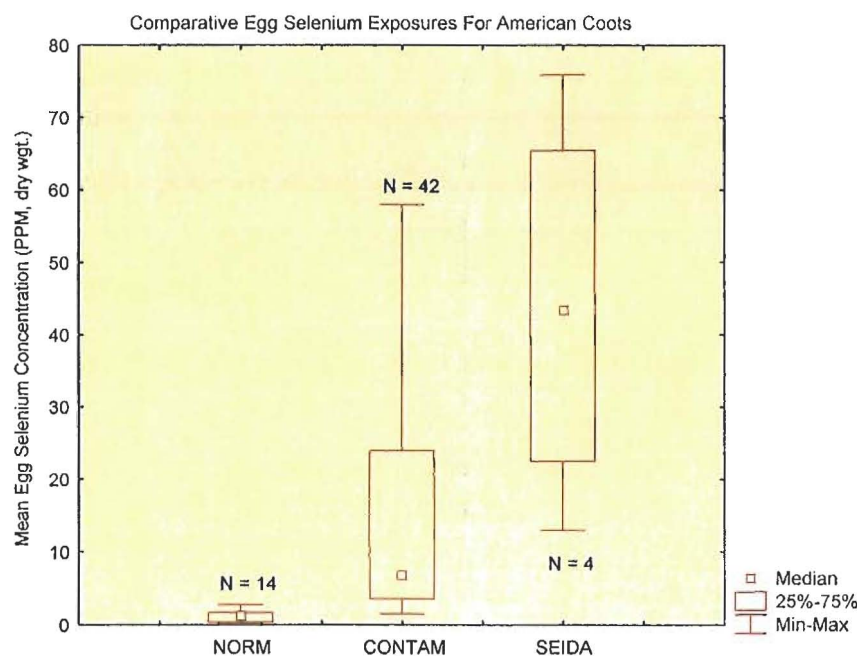
Furthermore, non-teratogenic and teratogenic selenium-induced embryo mortality are additive with a constant component of about 30–40 percent non-teratogenic embryo death being caused before the first signs of teratogenic death are induced (Stanley et al. 1996; Skorupa 1999; Detwiler 2002). Consequently, a predicted 8 percent rate of teratogenesis for this survey's sampling sites would project to roughly a 40–50% rate of total embryo loss. At this level of embryonic loss, post-hatch loss to selenium poisoning would also be expected, although the tools for quantitatively projecting post-hatch loss do not exist. However, at Kesterson Reservoir, post-hatch loss substantively exceeded embryonic loss due to selenium poisoning (Ohlendorf 1989). The bottomline risk assessment from the data collected for this study, is that the worst selenium-contaminated waterbird habitats in the Idaho phosphoria region are sufficiently contaminated to cause greater than 50% overall reproductive impairment.

On a mine-wise basis, there were three mines for which at least 5 eggs were sampled from mining influenced sites, Conda, Smoky Canyon, and Enoch Valley. For those three mines the estimated teratogenic risk was 4.2% for Conda, 15.2% for Smoky Canyon, and 28.4% for Enoch Valley. Those would project to estimated overall embryotoxicity rates of 35–45% for Conda, 45–55% for Smoky Canyon, and 60–70% for Enoch Valley at the worst-case scenario type of locations that this survey focused on.

Results for American Coots placed in a National Context – The single species of bird most extensively sampled during this survey was the American coot (Table 1). Fortunately, there is a very extensive data base for coot eggs sampled at numerous locations across the western United States (e.g., Seiler and Skorupa 2001). This data base was acquired as part of the U.S. Department of Interior's National Irrigation Water Quality Program(NIWQP). Again, fortunately, NIWQP also non-randomly targeted the identification and survey of worst-case

scenario study sites associated with agricultural sources of selenium pollution (e.g., Seiler 1995; 1998), so the NIWQP data base can be used for direct comparison with the results from this non-random worst-case scenario survey. NIWQP studies included the collection of 76 sets of American coot eggs (344 individual eggs) from 62 separate sampling sites distributed across ten western states (California, Colorado, Idaho, New Mexico, Montana, Nevada, Oregon, Utah, Washington and Wyoming). NIWQP egg collections were matched with water samples which allows the NIWQP data to be separated into results for clearly normal (NORM; N=14) background study areas where samples of waterborne selenium rarely, if ever, exceeded 1 ppb (ug/L) and clearly contaminated (CONTAM; N=42) study areas where samples of waterborne selenium rarely, if ever, were lower than 10 ppb (cf. Seiler et al. 1999). The remainder of the NIWQP sets of coot eggs (N=20) came from study areas that could not clearly be categorized with regard to an underlying level of waterborne selenium contamination due to variable results that included a mix of both background and elevated waterborne selenium values.

**FIGURE 14.** Comparison of NIWQP normal background (NORM) and contaminated (CONTAM) sets of coot eggs with Idaho survey results (SEIDA).



Comparison of the results from this survey for the Idaho phosphoria region (SEIDA) to the NIWQP data base (Figure 14, above) reveals that the worst-case scenarios associated with phosphoria mining are comparable to, or worse, than the worst-case scenarios associated with irrigated agriculture (such as California's Kesterson Reservoir). In other words, the hottest sampling sites discovered during this brief survey of the Idaho phosphoria region were hotter than the hottest sampling sites discovered during approximately a decade of sampling across ten states for the NIWQP.

However, the potential for damage to avian populations depends not only on how contaminated (hot) a site is, but also on how attractive it is to breeding water birds. What made Kesterson Reservoir such a large scale catastrophe was that it was highly contaminated AND it attracted thousands of breeding water birds each spring. This brief survey did not discover any sites that were suspected of exposing inordinately high numbers of breeding water birds. Although this survey was not designed to census bird numbers, the authors gained the qualitative impression that none of the sites surveyed supported more than a few hundred breeding waterbirds, and most of the sites surveyed probably supported substantially fewer breeding waterbirds.

## CONCLUSIONS

1. Wetlands and impoundments that provide potential breeding habitat for water birds and that contain 50 ug/L selenium or more during the egg-laying season for birds are relatively common in Idaho's phosphoria region. Many of these wetlands are vernal wetlands (present only during the spring) which previous water sampling surveys appear to have completely neglected in favor of sampling rivers, streams, and perennial impoundments (e.g., Montgomery-



Watson 1998; 1999). Because waterborne Se concentrations are highest in vernal melt and run-off, and decline substantially by fall (Presser et al., Draft Manuscript), vernal wetlands may often provide the highest risk habitats for breeding water birds. The highest Se concentration (nearly 800 ppm, dry wgt.) ever reported for a sample of aquatic invertebrates (to these author's knowledge anyway) was found at one such vernal wetland during this survey (Table 1). It is strongly recommended that a more extensive and detailed survey of vernal wetlands in Idaho's phosphoria region be conducted as soon as possible. The general lack of data for such vernal wetlands constitutes a critical data gap that could profoundly influence the outcome of regional risk assessments.

2. With egg selenium concentrations ranging as high as 80 ug/g, dry weight, it is a statistical certainty that avian mortality due to selenium exposure is occurring in several of the areas sampled during this survey (Conda, Smoky Canyon, Enoch Valley). Two highly suggestive cases of selenium-induced embryo teratogenesis were documented, but neither is considered to be an absolutely definitive (slam-dunk) example of selenium poisoning. In both these cases the eggs were only exposed to threshold concentrations of selenium for adverse effects (although still clearly elevated exposures), thus allowing a margin of uncertainty regarding causation of the relatively mild embryonic abnormalities that were observed. Unfortunately, the most highly exposed eggs were from nests that, by pure chance, were discovered and therefore sampled too early in the incubation cycle to yield assessable embryos. Had this been a more expensive longitudinal monitoring study, rather than a very inexpensive (total budget of \$7,000 for field work) grab and run survey, sampling of eggs could have been delayed until each egg sampled was at an advanced stage of incubation and would have been highly likely to yield an assessable embryo. It is strongly recommend that such a longitudinal monitoring study, focused on confirmed and suspected highly contaminated habitats in Idaho's phosphoria region be conducted as soon as possible.

3. On the basis of levels of selenium exposure in avian eggs at non-randomly chosen worst-case sampling sites, the Idaho phosphoria region presents the potential for ecotoxicological risks to breeding water birds that equals or exceeds any region, and source of selenium (agricultural wastewater, fly ash, etc.) previously reported in the scientific literature (see Skorupa 1998 for a comprehensive review). During this brief survey, that high potential for risk did not appear to be realized on a large scale due to the relative scarcity of breeding water birds at most sites surveyed. However, the authors feel very confident that there are many, many, high risk sites in the phosphoria region that have yet to be sampled or assessed for levels of avian use. Furthermore, levels of avian use can change radically from year-to-year depending on numerous factors, thus a single-year, extremely brief survey should not be viewed as definitive regarding the degree to which potential risk is being realized. Provisionally, though, realized risk should generally be considered relatively low. Concerns for species of special status should be evaluated as soon as possible.

4. The most important and definitive conclusion that can be drawn from this survey is that further, targeted, data collection on avian exposure to selenium at highly contaminated sites is strongly warranted. The worst-case sites sampled during this brief survey confirmed that pathways for extraordinary avian exposure to selenium are relatively common in the Idaho phosphoria region, but remain very poorly characterized. Unfortunately, a major risk pathway for birds, vernal wetlands, was not characterized at all prior to this survey. Considering this study to be equivalent to a low-tier screening survey, the results clearly indicate that elevation to the next higher tier of data collection is warranted.

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## **APPENDIX A**

### **AGING GUIDE FOR AMERICAN AVOCET EMBRYOS**



FIGURE 1:

**FRESH AMERICAN AVOCET EGG.**

IN A FERTILE EGG, A BROAD WHITE RING SURROUNDS A CLEAR CENTRAL REGION (AREA PELLUCIDA). IN AN INFERTILE EGG, THERE WILL ONLY BE A SMALL WHITE DOT (ABOUT THE SIZE OF THE AREA PELLUCIDA IN A FERTILE EGG). THE EGGS PICTURED HERE WERE ALL FERTILE, BUT THE AREA PELLUCIDA DOES NOT SHOW VERY WELL, SO IT HAS BEEN OUTLINED IN PEN ON THE CENTRAL PHOTO TO PROVIDE AN EXAMPLE OF SCALE.

(J.P. SKORUPA, U.S. FISH & WILDLIFE SERVICE)

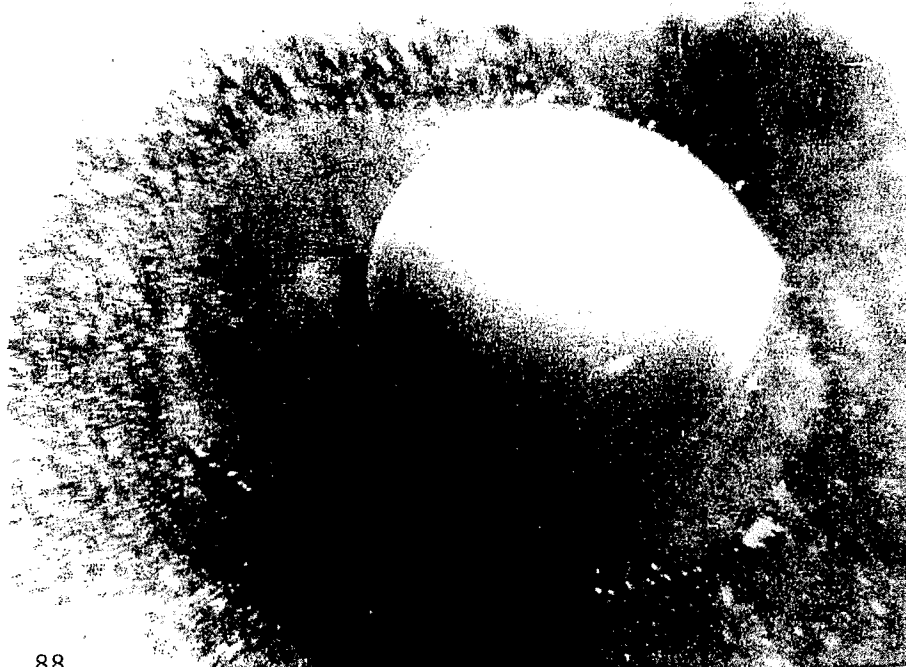
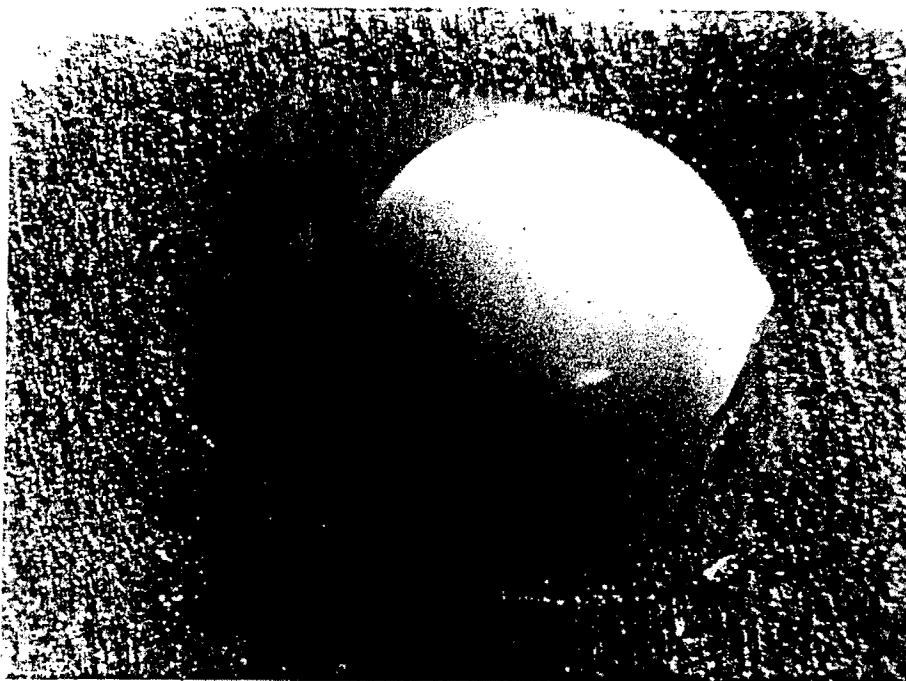


FIGURE 2:

**AMERICAN AVOCET EGG AFTER 3 DAYS  
INCUBATION.**

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE (KNOWN AS THE "STREAK" STAGE) ARE THE HEART AND THE MAJOR BLOOD VESSELS OF THE YOLK SAC. IN THESE PHOTOS THE HEART IS THE DARK SPOT IN THE UPPER CENTRAL AREA OF THE YOLK SAC. IF THE EMBRYO IS ALIVE, YOU WILL BE ABLE TO NOTICE THAT THE HEART IS BEATING EVEN AFTER YOU HAVE PLACED THE SAMPLE IN A SAMPLE JAR.

(J.P. SKORUPA, U.S. FISH & WILDLIFE  
SERVICE)

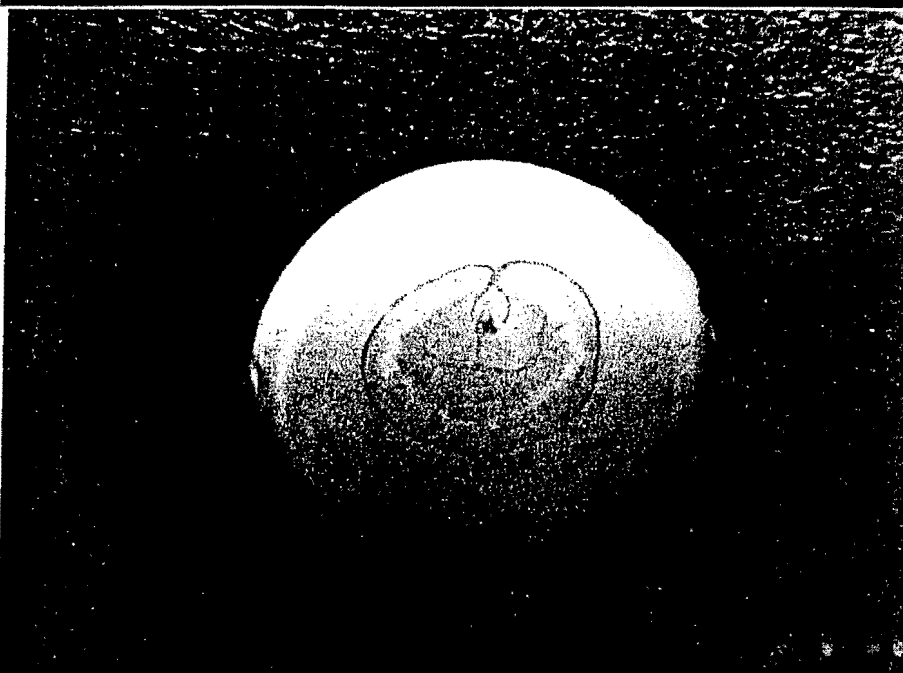
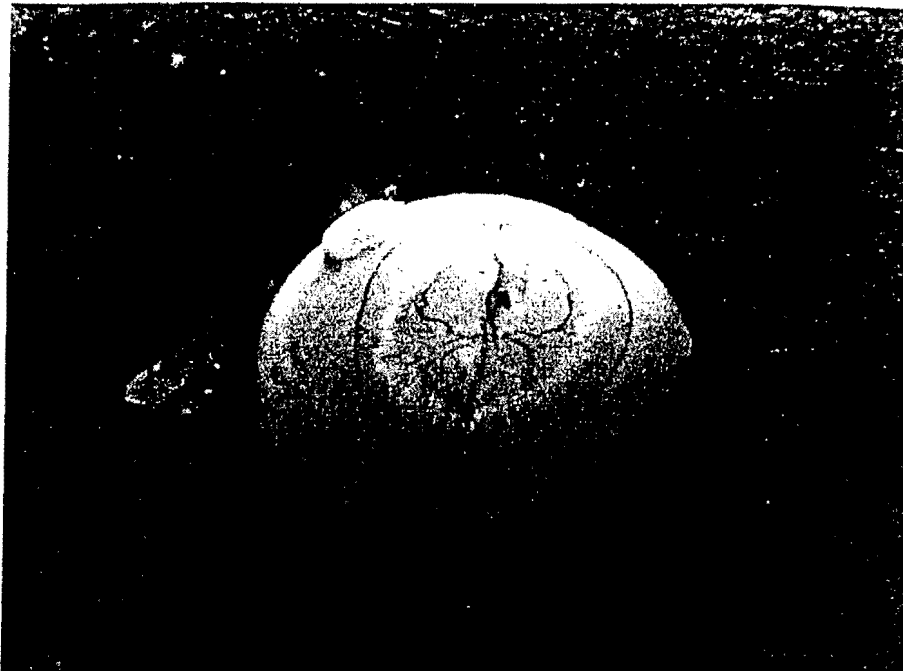


FIGURE 3:

AMERICAN AVOCET EGG AFTER 6 DAYS  
INCUBATION.

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE ARE THE MID-BRAIN BUBBLE AT THE POSTERIOR END OF THE HEAD (ABOVE THE EYES), THE EYES (WHICH SHOULD BE VERY DISTINCTLY VISIBLE AND DEVELOPED) AND THE LIMB BUDS. THE LIMBS ARE STILL PADDLE-SHAPED WITH ONLY SLIGHT DEFINITION (IF ANY) OF DIGITS. THE ENTIRE EMBRYO IS STILL NAKED AND ONLY ABOUT 2 CM IN LENGTH.

(J.P. SKORUPA, U.S. FISH & WILDLIFE  
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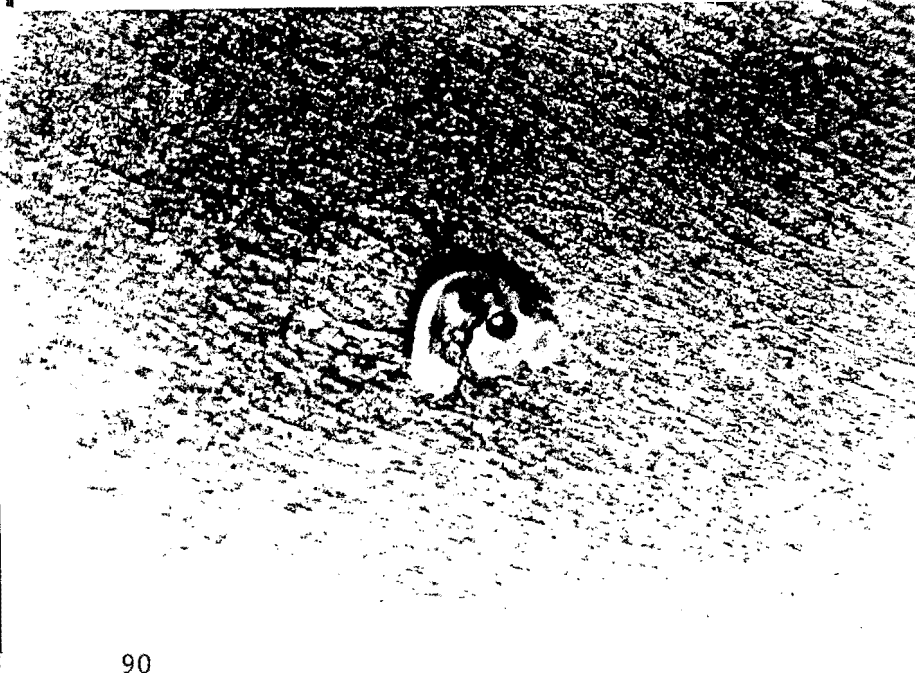
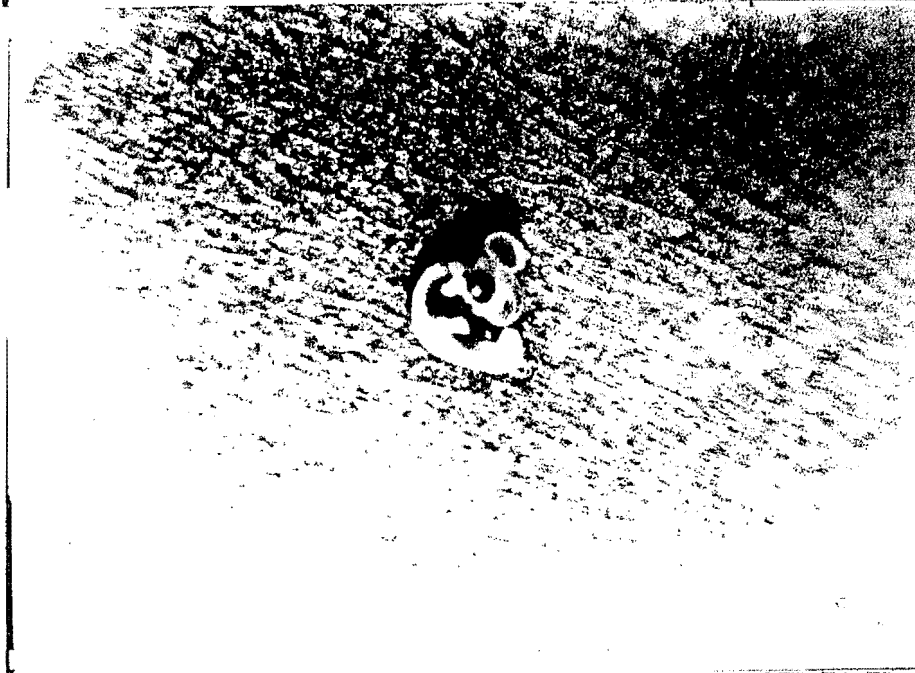




FIGURE 4:

AMERICAN AVOCET EGG AFTER 9 DAYS  
INCUBATION.

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE INCLUDE A MORE TYPICALLY SHAPED HEAD WITH THE MID-BRAIN BUBBLE ABSENT (UPPER PICTURE) OR ONLY SLIGHTLY VISIBLE (LOWER PICTURE), A DISTINCTLY FORMED BILL THAT IS STILL SHORTER THAN THE WIDTH OF THE HEAD, EXTREMELY PROMINENT EYES, AND MORE FULLY DEVELOPED LIMBS MAKING THE TRANSITION TO DISTINCTLY VISIBLE DIGITS. AT THIS STAGE THE EMBRYO IS STILL COMPLETELY NAKED, ALTHOUGH THE SKIN IS BEGINNING TO SHOW DISTINCT "PIMPLING" IN THE REGIONS OF THE MAJOR FEATHER TRACTS

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FIGURE 5:

**AMERICAN AVOCET EGG AFTER 12 DAYS  
INCUBATION.**

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE INCLUDE A BILL THAT IS LONGER THAN ONE WIDTH OF THE HEAD, LARGE EYES WITH DISTINCTLY VISIBLE EYELIDS THAT ARE JUST BEGINNING TO CLOSE DOWN, FULLY DEVELOPED LIMBS AND THE FIRST SIGNS OF FEATHERS IN THE CAUDAL REGION (A PEPPERED RUMP, AT LATE DAY 12, EARLY DAY 13). THE MID AND UPPER BACK, NECK, AND HEAD ARE ALWAYS STILL NAKED AT DAY 12. AS ILLUSTRATED IN THE UPPER THIRD OF THIS FIGURE, THE YOLK SAC IS STILL LARGER THAN THE EMBRYO (LYING IN THE SHADOWS TO THE LEFT OF THE YOLK SAC) AT THIS STAGE.

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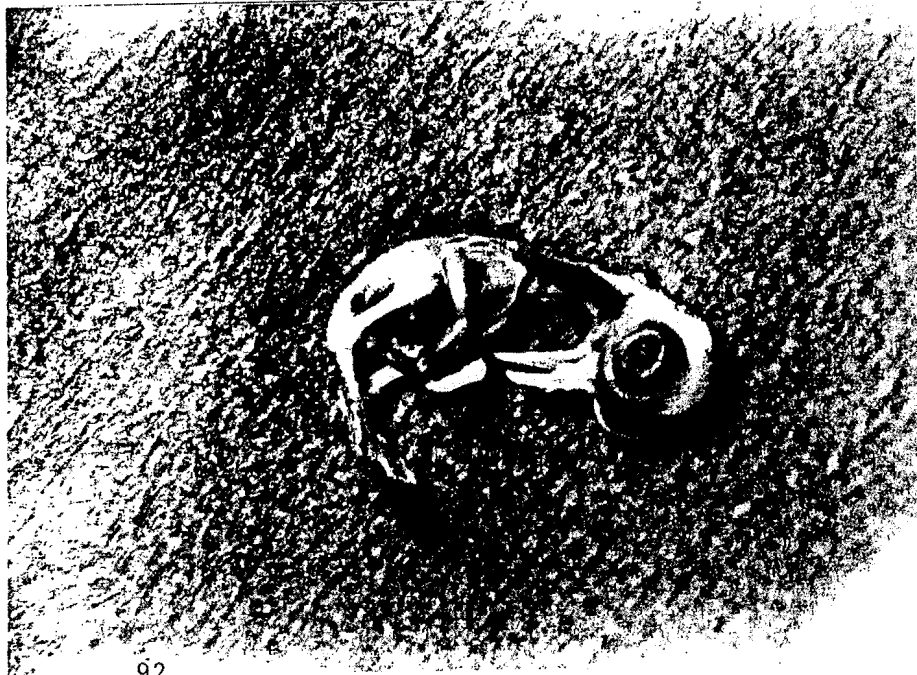
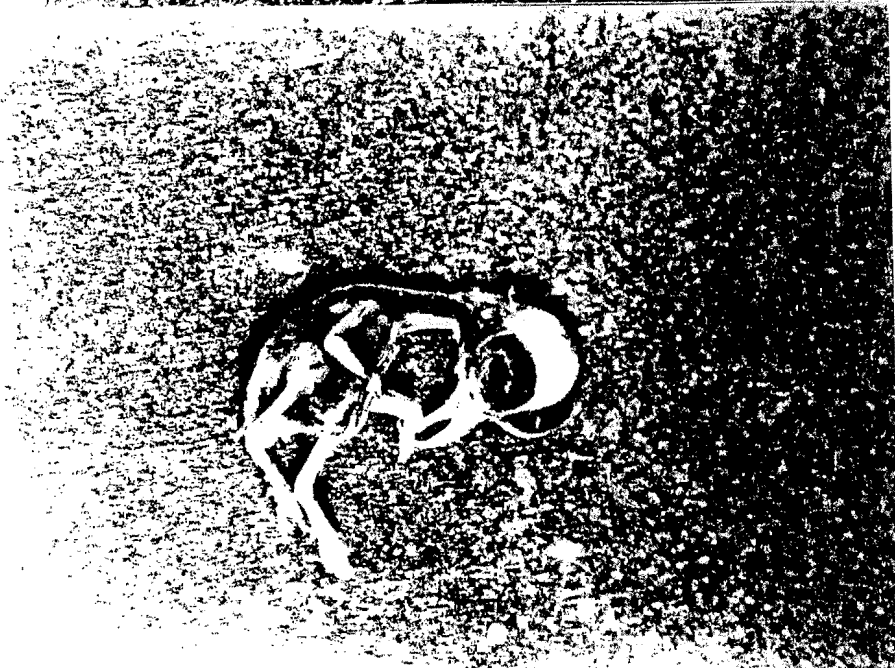


FIGURE 6:

AMERICAN AVOCET EGG AFTER 15 DAYS  
INCUBATION.

THE MOST PROMINENT CHARACTERISTICS AT  
THIS STAGE INCLUDE FEATHER DEVELOPMENT  
THAT RESULTS IN A SLIGHTLY TO WELL  
"PEPPERED" HEAD, EYELIDS CLOSING DOWN  
TO MORE OF A HORIZONTAL SLIT THAN A  
CIRCULAR OPENING, AND OBVIOUSLY  
VISIBLE EGG TOOTH & TOENAILS.  
OVERALL, THE BODY IS STILL RATHER  
SPARSELY FEATHERED SUCH THAT THE  
JUGULAR VEIN IS STILL CLEARLY VISIBLE.

(J.P. SKORUPA, U.S. FISH & WILDLIFE  
SERVICE)

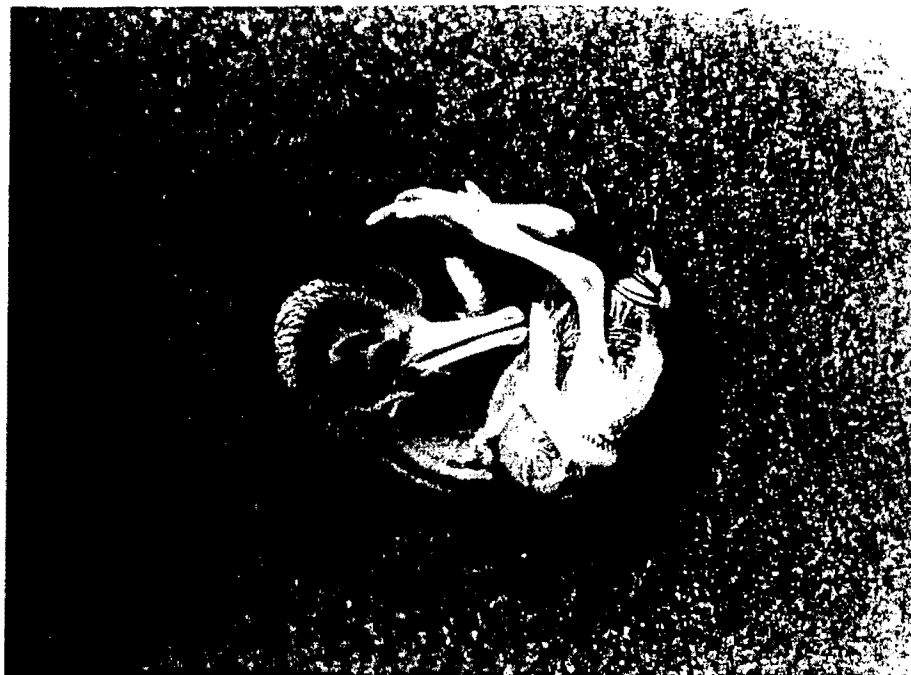




FIGURE 7:

**AMERICAN AVOCET EGG AFTER 18 DAYS  
INCUBATION.**

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE INCLUDE MORE FULLY FEATHERED FACIAL, HEAD, AND NECK REGION, CLOSED EYES, AND ABSENCE OF NARE CAPS. JUGULAR VEIN NO LONGER CLEARLY VISIBLE, BUT MAJOR FEMORAL BLOOD VESSELS STILL CLEARLY VISIBLE. THE EYELIDS ARE STILL OBVIOUSLY BALD. THE LEGS AND FEET STILL HAVE A THIN "BONY" APPEARANCE.

(J.P. SKORUPA, U.S. FISH & WILDLIFE SERVICE)





FIGURE 8:

AMERICAN AVOCET EGG AFTER 20 DAYS  
INCUBATION.

THE MOST PROMINENT CHARACTERISTICS AT THIS STAGE INCLUDE VERY FLESHY AND BULKY LOOKING LEGS AND FEET (WITHOUT CLEARLY VISIBLE BLOOD VESSELS), PIGMENTED/FEATHERED EYELIDS, AND THICK FEATHERING OF THE HEAD. BETWEEN THIS STAGE AND HATCHING (AT 25 DAYS), THE PRIMARY EXTERNAL CHANGES IN APPEARANCE ARE THE CONTINUING "BULKING-UP" OF THE LEGS AND FEET AND THE PROGRESSIVE REDUCTION AND ABSORPTION OF THE YOLK SAC.

(J.P. SKORUPA, U.S. FISH & WILDLIFE  
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